A Flemish Hydrogen Strategy

2025 – 2030

WATERSTOF INDUSTRIE CLUSTER

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The Hydrogen Industry Cluster

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1 Introduction and purpose

As a region, Flanders has the right assets to occupy a **TOP POSITION** in Europe for rolling out a hydrogen economy. Hydrogen has dominated political agendas for some time now. It is seen as a key to the energy transition and, as a sustainable technology, is being positioned at the forefront of economic (recovery) policy. The hydrogen-related objectives set at the EU level were translated into an ambitious European hydrogen strategy in July 2020.[1]

The Flemish government also committed to hydrogen in its 2019 coalition agreement, and the federal government included hydrogen in its October 2020 coalition agreement. This Hydrogen Industry Cluster paper provides a more concrete interpretation of an **INTEGRATED HYDROGEN STRATEGY** in response to the Flemish Government's notice of 13 November 2020, the 'Vlaamse Waterstofvisie' (The Flemish Hydrogen Policy Strategy). To lend the industry the confidence it needs to transition from demonstrations to the broader rollout of technology and infrastructure, concrete targets for hydrogen production and its various uses are needed.

The **SOLID PRESENCE** of the full hydrogen chain in Flanders – from production to technological development and applications to end-users – is established fact. Hydrogen technology has been successfully developed and demonstrated over the past decades. What's more, the infrastructural conditions in Flanders, to include the ports, pipeline infrastructure, industrial clusters and dense transport networks, are extraordinarily conducive to a shift towards a hydrogen economy.

The combination of a favourable political climate, the available knowledge and experience, and positive environmental factors make implementing hydrogen technology in Flanders realistic. Not only could this contribute to **CARBON NEUTRALITY GOALS**, but it could also stimulate the **DEVELOPMENT OF A DOMESTIC MARKET** for Flemish hydrogen companies. Flanders' limited renewable energy sources for hydrogen production do not pose an insurmountable problem.

For a transition period, current hydrogen production can also be produced using CCS (carbon capture and storage) and other production methods. Hydrogen is also available as a **BY-PRODUCT** in the industry. Flemish ports make it possible for Flanders, as a region, to develop a hub for the **IMPORT OF SUSTAINABLE HYDROGEN** as well as for its production.

The Hydrogen Industry Cluster ('Waterstof Industrie Cluster' or WIC) aims to employ its strategic Flemish hydrogen policy strategy to introduce an **AMBITIOUS YET REALISTIC ACTION PLAN** that involves Flanders in global hydrogen affairs. To this end, the proposed action plan must be in line with Flemish, federal, and European hydrogen-related goals.

The hydrogen industry has signalled its willingness to invest in hydrogen, convinced that this technology can contribute to rendering many key sectors carbon neutral and yielding an economic return for Flanders. However, it requires a framework that inspires confidence, legislation that facilitates technology instead of hindering it, and targeted support to (partially) close the gaps in the business cases.

[1] https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

2 Why hydrogen?

2.1 Hydrogen's role in the energy transition

Hydrogen will play a key role in Europe's transition to the carbon-neutral energy system by 2050 set out in the Green Deal. In addition to a dramatic increase in the availability of renewable energy and electrification where possible, the future energy supply also requires molecules. European Commission models reveal that by 2050 around 50% of Europe's final energy demand must be met by electricity to limit global warming to 1.5°, as stipulated in the Paris Agreement. In effect, nearly half of the final energy demand must be met by **MOLECULAR ENERGY CARRIERS**.[2]

Liquid and gaseous energy carriers will remain essential as fuel for applications where electricity (stored in batteries, for example) is either insufficient or impractical. Molecules are also still required by process manufacturing to synthesise chemical products and materials. Finally, liquid and gaseous energy carriers are essential for the large-scale energy storage and transport required to ensure that the supply and demand of energy remain balanced everywhere and at all times.

Hydrogen, whether pure or in a derivative form, provides an excellent basis for rendering molecular energy demand carbon-neutral, especially for sectors in which alternatives are scarce or unavailable. These sectors – and the priorities that can be identified in relation thereto – will be explored in greater detail in the next roadmap. Hydrogen is not a *silver bullet*. However, it is a **KEY THAT UNLOCKS A GREAT MANY DOORS** and, in some cases, may be the only one with access to a carbon-neutral energy system.

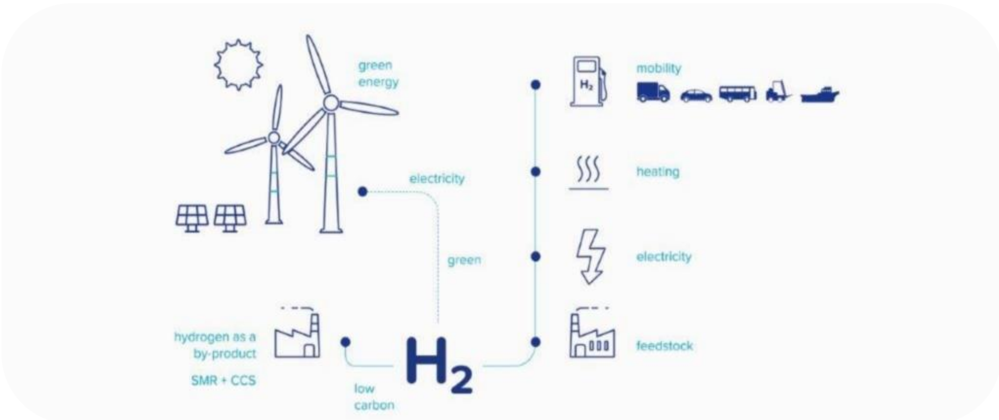

Figure 1: hydrogen production and potential applications

Hydrogen has tremendous system value in terms of energy system flexibility (sector coupling) and the capacity to facilitate renewable energy penetration of sectors where sustainability transformation is particularly challenging (sector integration). In general, hydrogen and *power to gas* (P2G) are some of the few energy storage options capable of providing significant seasonal storage capacity for the energy market at an affordable rate. A hydrogen backbone in Belgium could flexibly connect P2G conversion and storage capacities at different locations.

2.2 The colours of hydrogen

The production method determines hydrogen's **COLOUR**. Most hydrogen, today, is produced by thermal cracking of natural gas *(steam methane reforming* - SMR). This is known as **FOSSIL OR GREY**

[2] https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en_0.pdf p.72

HYDROGEN, given that the by-product contains CO_2. When fossil CO_2 is captured and stored *(carbon capture and storage* - CCS), **LOW-CARBON OR BLUE** hydrogen is the result. Low-carbon hydrogen is also the hydrogen released as a residual product in other production processes, such as chlorine production via the chloralkaline process.

Hydrogen can also be produced entirely from renewable sources. Electrolysis of water (i.e., simple electrolysis) is the most mature technology to be implemented in both large-scale and small-scale production models. During electrolysis, electricity is used to split water (H_2O) into hydrogen (H_2) and oxygen (O_2). If the electricity is derived from renewable sources and the CO_2 footprint of the entire process – from the generation of electricity to hydrogen delivery of the right pressure and purity – is below a certain limit[3], the hydrogen can be labelled **RENEWABLE OR GREEN**.

Given that only low-carbon and renewable hydrogen are capable of making a substantial contribution to a carbon-neutral society, this paper focuses exclusively on renewable and low-carbon hydrogen (jointly **SUSTAINABLE**) hydrogen.

This also harmonises with the EU hydrogen strategy, where renewable and low-carbon hydrogen are considered elements that contribute to a carbon-neutral industry, transport and built environment. Low-carbon (blue) hydrogen is regarded as a transitional source intended to boost the emerging market; however, the demand for new applications must be stimulated in tandem. Low-carbon hydrogen is a crucial step for acting quickly and reducing global warming now. In the long term, approaching 2040 and 2050, only renewable hydrogen produced from renewable and non-fossil-fuel sources will be the standard.

[3]For RFNBOs (e.g., hydrogen), RED II stipulates that there must be at least a 70% reduction (savings) in greenhouse gas emissions vis-a-vis fossil fuel comparators. Reference: https://ec.europa.eu/jrc/en/jec/renewable-energy-recast-2030-red-ii

3 Policy context

3.1 Europe

The **GREEN DEAL** drawn up at the end of 2019 made Europe the first continent to set the goal of going climate-neutral by 2050. The Green Deal links environmental and climate change goals to economic opportunities, and hydrogen is regarded as a cornerstone of that policy. As a continent, Europe aims to excel in this technology to achieve greater energy independence. At the same time, it regards this as a profitable approach.

The European Commission introduced its own **HYDROGEN STRATEGY** in July 2020. The plan, coupled with the requisite investment incentives, should pave the road for the European hydrogen industry. The hydrogen strategy consists of three phases, with phase one launching between 2020-2024, phase two between 2025-2030, and phase three between 2030-2050. A gradual scaling up of the electrolysis capacity from 6 GW in 2024 to 40 GW in 2030 is an integral part of the strategy.

In terms of timing and priorities, this Flemish hydrogen strategy proposal aims to tie in with the first two phases of the European strategy. For instance, it states that sustainable hydrogen should initially be used as a raw material in industry. The transport sector is also regarded as a promising sector, with a focus on heavy and long-distance transport. To that end, hydrogen can also serve as a building block in synthetic fuels where needed.

Phase one of the EU strategy targets the implementation of **LARGE-SCALE ELECTROLYSIS PROJECTS** in proximity to industry with a hydrogen demand. These initial 'hydrogen hubs' can subsequently be linked to transport applications. **HYDROGEN CLUSTERS** will be interlinked, e.g., by converting the existing natural gas network or by constructing a new hydrogen network, in phase two. Towards 2050, with even greater domestic electrolysis capacity as well as large-scale imports, hydrogen will become an **INTEGRAL PART** of the energy system and will be widely used in sectors that are less equipped to go carbon-neutral.

Current and new instruments will need to translate the objectives into an investment agenda. Relevant examples include:

- The Clean Hydrogen Alliance
- Clean Hydrogen for Europe (the successor to the Fuel Cells and Hydrogen Joint Undertaking)
- The ETS Innovation Fund
- The Green Deal Call
- The NextGenerationEU Recovery Facility
- The Important Projects of Common European Interest (IPCEIs)

A **HYDROGEN IPCEI** already provides a point of departure for implementing large-scale hydrogen projects in Flanders. IPCEI allows Member States to ease the implementation rules that normally apply to state aid. The Belgian government launched an 'expression of interest' regarding the hydrogen IPCEI in March 2020. Flanders submitted several dozen project proposals, all of which are currently under review. At the same time, the Flemish government, as the competent regional level, is looking into potential funding support for the IPCEI projects.

The **'Green Octopus'** programme was jointly developed by Flanders, the Netherlands and Germany within the framework of the European IPCEI programme. The Green Octopus aims to create an industrial hydrogen ecosystem between Flanders and the Netherlands that extends to France (Dunkirk) and Germany, where supply and demand of green hydrogen are linked and where the ports act as key facilitators.

3.2 Flanders and Belgium

The 2019-2024 Flemish Coalition Agreement and various policy documents (Economy, Energy, Mobility) underline the pivotal role that hydrogen can play in the Flemish energy and climate transition and, at the same time, to create new economic opportunities in the global hydrogen technology and application growth market. The coalition agreement even expresses the intention to take on a pioneering role in Europe. The Flemish Energy and Climate Plan also refers to the right hydrogen-related applications and priorities.

- The objectives stated therein were reinforced in September 2020 when it was announced that hydrogen will play a major role in the Flemish recovery policy. Funding allocation to specific projects in the pipeline will be reviewed. Under the recovery plan and IPCEI support, approximately EUR 125 million would go to hydrogen.

At the level of the Flemish authorities, an initial concrete step was taken on 13 November towards the creation of an integrated **Flemish hydrogen policy strategy**. The Flemish Minister of Economy and Innovation, Hilde Crevits, took this as an opportunity to submit a statement[4] to the government.

Several hydrogen-related priorities for Flanders, in line with the EU's hydrogen strategy, were proposed, e.g., as molecules in the Flemish industrial and energy supply, as well as to make the transport sector more sustainable.

Flanders aims to be at the forefront of technological developments in the wider hydrogen value chain. The goal is to achieve the necessary technological breakthroughs in the broad field of technology as a result of the support garnered from research and innovation.

The impetus and focus are rooted in an economic and innovative perspective but invite the participation of other policy areas such as transport, energy, the environment, and climate to arrive at a common vision and action plan. This roadmap is intended to provide the building blocks required to achieve an integrated vision at the Flemish level.

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[4] https://beslissingenvlaamseregering.vlaanderen.be/document-view/5FAD539C20B6670008000274

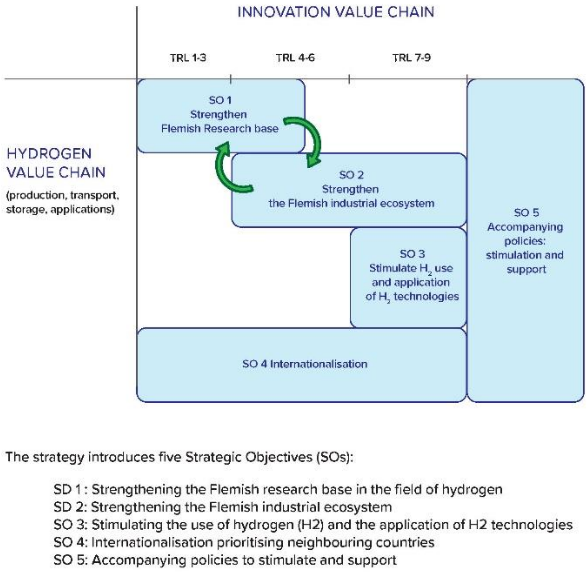


Figure 2: the proposed strategy for achieving the Flemish hydrogen vision by the Flemish government[5]

The formation of a federal government at the end of September 2020 led to a demonstrably increased interest in hydrogen at the **Belgian federal level** as well. Hydrogen is mentioned by name concerning the production of green hydrogen for industries and freight transport where electrification is not feasible. Moreover, there is a focus on how the production of low-carbon hydrogen and CO_2 capture, green gas-related pilot projects, power-to-x, etc. can be stimulated. In particular, this concerns the development of an H_2 and CO_2 backbone with maximum reuse of the natural gas infrastructure. Lastly, the potential of hydrogen trains is being investigated.

Belgium also participates in international partnerships such as the **Pentalateral Energy Forum**. The Forum is a politically driven, seven-nation partnership between governments, regulators, transmission system operators, and market players that aims to complete the internal energy market. Hydrogen is high on the agenda.

[5] Source: Statement to the Flemish government, Flemish Hydrogen Policy Strategy 'European frontrunner through sustainable innovation', p. 11.

4 Hydrogen in Flanders

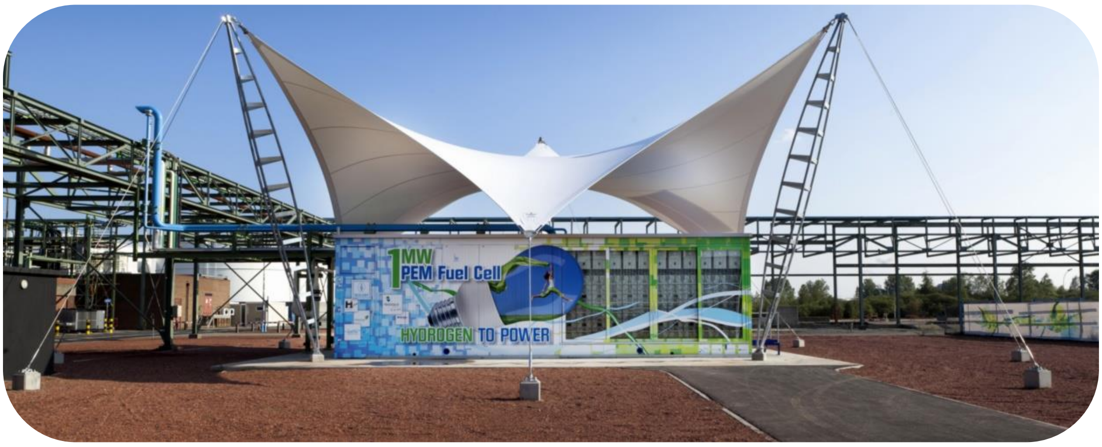
4.1 Successful hydrogen projects

Hydrogen has been used for decades as a raw material in various industrial processes. Around 45 years ago, Air Liquide installed an underground hydrogen pipeline network that connects large hydrogen production facilities and hydrogen end-users active across various sectors throughout France, Belgium, and the Netherlands. For the production of hydrogen, large-scale SMR plants are used as well as available residual hydrogen.

Air Liquide is in the process of commissioning its next-generation hydrogen production unit at its location on the Covestro site in the Port of Antwerp. This new technology will significantly boost the production process' energy efficiency and improve its overall ecological footprint. Even better, these installations can be powered by renewable energy sources such as biomethane.

Over the past decade, several green and low-carbon hydrogen initiatives have been launched by private enterprises or as part of (EU) projects. At the Colruyt Group site in Halle, the first electrolysis plant was built by Cummins-Hydrogenics; it uses the hydrogen produced for the propulsion of forklift trucks, heavy-duty tank dispensing, and a public filling station for passenger cars.

The filling station was upgraded in 2018 to a public filling station where passenger cars can currently refuel at 700 bar. Just two years prior, Air Liquide had already built a 350 and 700 bar public filling station in Zaventem. In 2012, the largest hydrogen fuel cell plant in the world was built with European technology at Solvay in the Port of Antwerp. The plant converted residual hydrogen as a by-product of chlorine production into 1 MW electricity.



In terms of vehicles, there are currently about forty hydrogen-powered passenger cars on the Flemish roads. E-Trucks Europe, with offices in Flanders (Lommel) and the Netherlands (Westerhoven), has already converted a dozen waste collection vehicles to hydrogen for projects at home and abroad. The first demonstrations with HGVs (Heavy Goods Vehicle) are currently taking place. VDL, with a key site in Roeselare, converted a 27-tonne lorry and a 44-tonne lorry to hydrogen. The HGVs are in operation and will refuel, among others at the DATS 24 (Colruyt Group) filling station in Halle.

De Lijn added five hydrogen-powered buses to its service in 2014, which operate in Antwerp and its environs. The buses were built by Van Hool, a world leader in H_2 buses. In terms of maritime transport, the Hydroville was built in 2018 by Compagnie Maritime Belge (CMB). This passenger shuttle uses a mixture of hydrogen and diesel in a 'dual fuel' solution and serves the Port of Antwerp.

In 2020, DEME commissioned a mobile plant for the electrification of the site installations at Blue Gate (Antwerp). The plant fundamentally runs on solar energy with short-term electricity stored in batteries and long-term storage provided by a hydrogen cycle (electrolysis, H_2 storage and conversion to electricity via a fuel cell).

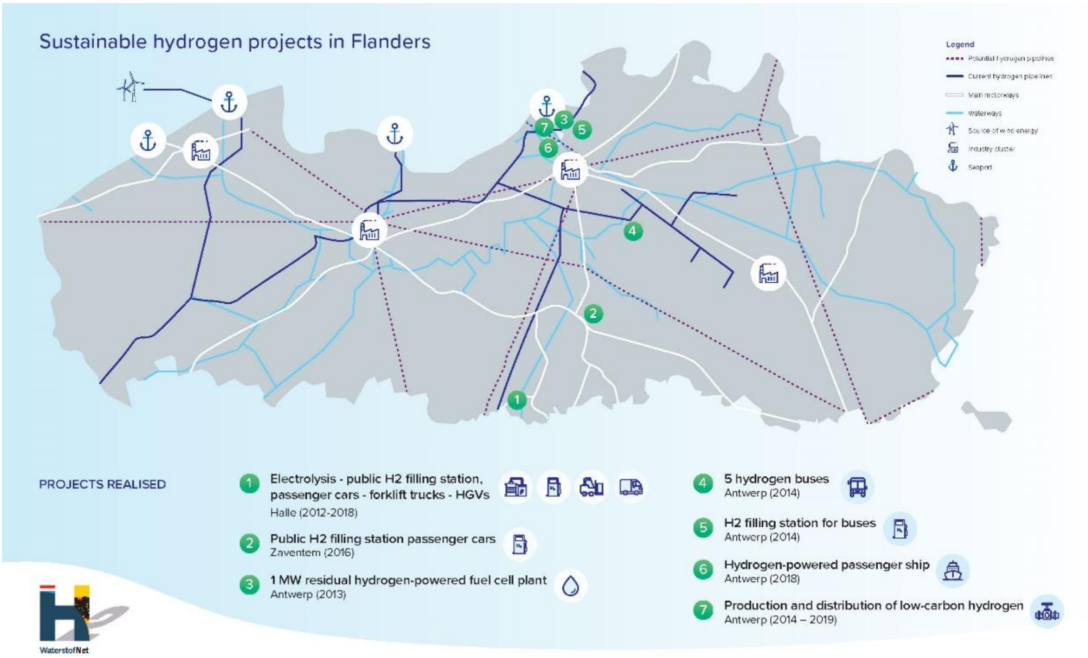


Figure 3: Successful hydrogen projects in Flanders (2012 - 2020)

4.2 A solid industrial network

The aforementioned projects were executed by companies with offices in or conducting important activities in Flanders. Hydrogen-related knowledge and expertise in Flanders are distributed across the entire hydrogen value chain. The majority of this industrial network is incorporated in **The Hydrogen Industry Cluster**. The Hydrogen Industry Cluster currently has over 60 members, accounting for an estimate of over **500 FTE** employees in Flanders, solely employed in hydrogen-related activities. There are ambitions to scale up this figure significantly in light of upcoming projects. Companies that belong to the network obviously have a much higher level of employment; however, the network does not necessarily include all companies with hydrogen-related activities or objectives in Flanders.

Figure 4: the approximately 65 members of The Hydrogen Industry Cluster spread across Flanders and the Netherlands

The **VALUE CHAIN** includes players involved in green energy production, hydrogen production, transport, and storage, as well as players active in hydrogen technology and applications up to the final end-users. A switch to a hydrogen-based economy will enable these companies to increase their product sales on the domestic market, create more local jobs, and strengthen their export position – all at the same time.

Figure 5: the distribution of The Hydrogen Industry Cluster members across the H_2 value chain

Where **HYDROGEN PRODUCTION** is concerned, Flanders has a robust contingent of tech players, active in electrolysis (alkaline and PEM) and reforming. And Flanders already has an underground private hydrogen pipeline network for the **TRANSPORT** of hydrogen. Conversion of the natural gas pipelines is also a viable option due to the dense natural gas network. There are large construction companies with expertise in pipeline construction or with a focus on hydrogen plant construction.

There is also a multitude of **TECH PARTIES** and actors involved in **HYDROGEN APPLICATIONS**, such as compressors, storage tanks, hydrogen filling stations, various vehicles (buses, passenger cars, waste collection vehicles, HGVs, ships, etc.), fuel cells, combustion engines, boilers, CHPs, and more. There are also large industrial **CONSUMERS** in the petrochemical industry, particularly in refining, located in Flanders. Partnerships have been set up with several **KNOWLEDGE INSTITUTIONS** for basic and applied research.

The group of The Hydrogen Industry Cluster members primarily active in the Netherlands is also on the rise. However, given that this policy strategy focuses on Flanders, their activities and expertise have purposefully been excluded. That said, The Hydrogen Industry Cluster would like to underscore that **DUTCH PARTIES** also possess unique hydrogen-related knowledge and expertise, for example, in hydrogen refuelling infrastructure, constructing hydrogen-powered vehicles, and fuel cell development and production.

This only serves to re-emphasise that Flanders and the Netherlands should regard each other as **PREFERRED COOPERATION PARTNERS**. To this end, a foundation was laid at the summit of 4 November 2020, attended by Minister President Jan Jambon and Prime Minister Mark Rutte.[6]

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6 https://www.vlaandereninnederland.be/sites/default/files/atoms/files/4%20november%202020%20Gezamenlijke%20Verklaring%20Vlaams%20Nederlandse%20Top.pdf

4.3 H_2 SWOT analysis

Strengths	Opportunities
• Strong market players (see WIC) with hydrogen experience • Great electricity and gas interconnectivity with neighbouring countries, e.g. green electricity and gas imports • Major ports with offshore wind farm connections and hydrogen import opportunities • Potential users: extensive and growing inland navigation (modal shift) • Potential users: logistics hub (e.g. freight transport) • Users: large petrochemical sector • Offshore expertise	• Harmonisation with EU policies (hydrogen strategy instruments, IPCEI, Green Deal, etc.) • A government policy strategy that is open and invites companies to formulate a bottom-up policy strategy • North Sea-based cooperation between Member States, especially co-op opportunities with the Netherlands • Large industrial clusters in the ports represent opportunities for an integrated approach • Basic gas infrastructure (H_2 and gas pipelines) in place • Multinationals with headquarters (decision-making centres) abroad are interested in investing where the H_2 investment climate is most advantageous

Threats	Weaknesses
• More affluent neighbouring countries with larger budgets • Neighbouring countries with ambitious H_2 targets • Limited budget for new investments post pandemic • Ambiguities in the legislative framework (Flemish - federal - EU)	• There is an official hydrogen policy strategy, but no concrete targets yet • Domestic market development is limited vis-a-vis Flemish tech players • Low local renewable energy capacity and high electricity costs • H_2-related activities at knowledge institutions are not streamlined • Piecemeal H_2-related competences and complex legislation • Current H_2 energy carrier applications remain scarce • Lack of funding for large-scale pilot projects

This means that, as a region, Flanders has a robust industrial network populated by key hydrogen players and brimming with hydrogen experience. Add to that a favourable political climate and excellent infrastructural conditions, e.g., several seaports, a dense natural gas network and logistics hubs, and Flanders claim to significant **HYDROGEN ASSETS** is substantiated even more convincingly.

Nevertheless, that does not detract from the numerous **CHALLENGES** still standing in the way of the transition to a hydrogen economy. Nor does it diminish certain inherent risks. It makes sense then that a comprehensive SWOT analysis would help identify and summarise the strengths, weaknesses, opportunities, and threats for Flanders related to hydrogen.

Policy, regulation, limited local renewable energy capacity, and high electricity costs – for which no compensatory funding exists as of yet – are key **WEAKNESSES** suffered by Flanders. Access to cheap renewable energy is crucial for making business cases for large-scale electrolysis projects affordable. In that respect, Flanders is at a disadvantage compared to its neighbour, the Netherlands, even though it shares similar conditions conducive to introducing a hydrogen economy.

An integrated official policy strategy has the potential to inspire sectoral confidence and therefore hydrogen investments. In addition, it empowers Flanders to capitalise on the opportunities (and funding) streaming in from the EU. However, the complex interplay of competences in Belgium makes a uniform policy strategy at the Belgian federal level tricky. That is why the purpose of this calculated hydrogen policy strategy is to provide the building blocks for this kind of integrated policy strategy at the Flemish level, relying on the notice to the Flemish government 'Flemish Hydrogen Policy Strategy' as a starting point. It can then later serve as inspiration at the federal level.

The absence of a guidance framework poses the inherent risk that developments in Flanders will be fragmented and uncoordinated, which could result in most hydrogen developments being conducted abroad. For that reason, a step-by-step, interlocking chain of various links is required. That will create a hydrogen ecosystem focused on the domestic market, but that is also capable of intersecting with and capitalising on foreign initiatives.

Flanders must first and foremost look into opportunities for cooperation at the Benelux level to form a sufficient counterweight to its French and German neighbours, which have concrete plans and budgets for hydrogen that range in the billions. Naturally, however, hydrogen developments in France and Germany, and especially in border regions, also represent opportunities for cooperation.

5 A Flanders H_2 roadmap

This chapter sets out concrete **TARGETS AND OBJECTIVES** for the various links in the hydrogen chain. The objectives are based on the policy strategies and aims of The Hydrogen Industry Cluster member companies, and there is a symbiotic relationship between these and a set of ambitious, yet realistic *targets*. The targets have been endorsed by all member companies, and as such imply their willingness to make the requisite investments provided that the government provides the framework and support required.

> The targets are formulated for 2025 with an outlook for 2030. This time frame aligns with the first two phases of the European Hydrogen Strategy, where the first five years are characterised by the successful implementation of specific hydrogen projects and demonstrations, and phase 2 involves a scaling up of these initiatives over the subsequent five years.

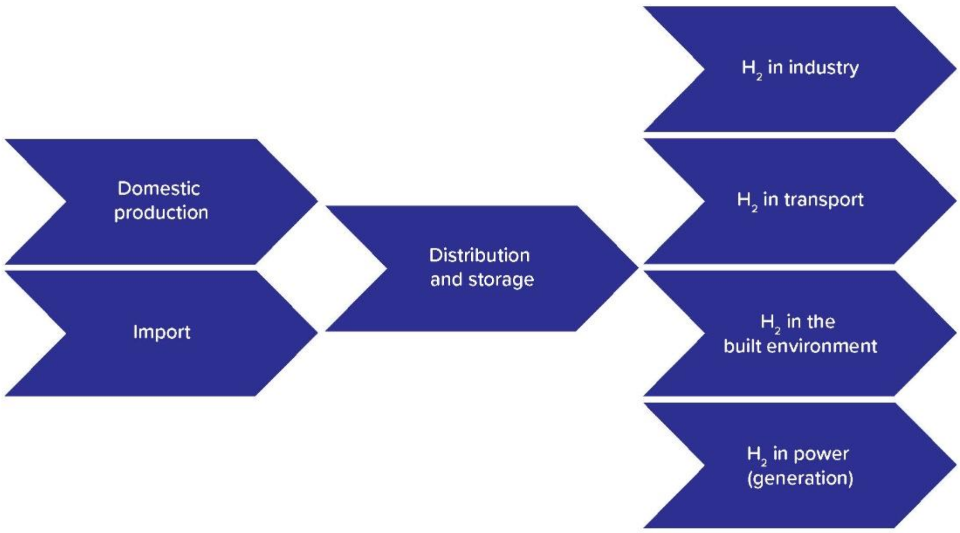

Figure 6: a diagram of hydrogen production, distribution and final applications

The left-hand side of the diagram illustrates how hydrogen is produced or imported into Flanders. This hydrogen is then conveyed to the final applications in various ways, whether or not involving temporary storage. There are four main applications associated with Flanders, which have also been ranked by priority, i.e., industry, transport, the built environment, and electricity production.

5.1 Domestic hydrogen production

5.1.1 Status and challenges

Today, only 4% of hydrogen used in the EU is generated renewably by electrolysis.[7] Most operational electrolysis plants are in the range of 100 kW to a few MW. That amount must increase, in future, to hundreds of MW or even one GW per plant or site.

SCALING UP has a significant bearing on not just achieving sufficient capacity to meet climate change goals, but on reducing hydrogen costs as well. Electrolysis plant investment costs are currently around EUR 1,000 per kW. These costs are predicted to drop by at least 50% around 2030 due to scaling up and standardised production.[8] However, the current production capacity is insufficient for large-scale electrolysis plants.

The combination of falling green electricity prices, more available renewable energy and increased efficiency, due to innovation, among others, should lead to a competitive hydrogen price for the various applications.

In Flanders, the current electrolysis capacity based on wind and solar energy is about 1 MW, accounting for an annual production of 100 tonnes of green hydrogen. Low-carbon hydrogen as a residual product is available in much higher quantities in the Port of Antwerp at around 100 kilotons a year and is already being used in industry.

That means that one of hydrogen production's major challenges is to realise **LARGE-SCALE ELECTROLYSIS PROJECTS** for the production of green hydrogen close to the market, i.e., in the industrial clusters. The most logical choice for implementing this kind of project would be the port environment, given the connection with onshore and offshore wind energy and the proximity of industrial clusters.

At the same time, the huge quantities of grey hydrogen produced – estimated at around 250 kilotons a year and 80% of which can be found in the Port of Antwerp – is a daunting challenge, as it needs to **BE MADE SUSTAINABLE EITHER THROUGH CARBON CAPTURE OR BY REPLACING IT WITH RENEWABLE SOURCES**.

Carbon capture in SMR production for storage or reuse requires more research through demonstration projects. Additional research/pilot projects are also needed to demonstrate how this works, as well as to gain efficiency in energy consumption and investment costs. Currently, the most mature CO_2 capture techniques are amine-based and cryogen-based. However, these techniques are both capital and energy-intensive. There are other, potentially cheaper and more efficient techniques being researched; however, these require further development.

Feasibility studies are being conducted on CCS techniques and related infrastructure at the North Sea Port and the Port of Antwerp. Other sustainable forms of hydrogen production, e.g., via gasification of waste or from syngas, pyrolysis or hydrogen panels, are still in a pilot phase.

In addition to these 'large-scale' hydrogen production plants, there should also be a focus on **SMALL-SCALE PRODUCTION** via electrolysis, where the producer and user are in close proximity. The advantage of small-scale production is that it does not require hydrogen transport, a primary concern of users outside the large industrial clusters. They will continue to lack local access to a hydrogen pipeline in

[7] https://www.fch.europa.eu/sites/default/files/Hydrogen%20Roadmap%20Europe_Report.pdf
[8] Hydrogen Europe, Strategic Research and Innovation Agenda (final draft), 2020, p.26-27

the future. Small-scale projects, as a result, have the potential to play an important role in the development of a hydrogen economy across a wider range of applications and locations.

Hydrogen can also be produced in an **INDIVIDUAL BUILDING OR BY A USER**, for example through electrolysis or via hydrogen panels. This hydrogen can be used to meet electricity and heat demand in the built environment, e.g., via a fuel cell or CHP.

5.1.2 2025 – 2030 Objectives

DOMESTIC PRODUCTION	2025 OBJECTIVES	2030 OBJECTIVES
LARGE SCALE:		
Large-scale electrolysis of water in port and industrial areas, maximum reliance on wind energy	200 MW installed capacity with a production of 15 kilotons of green hydrogen a year	500 MW installed capacity with a production of 35 kilotons of green hydrogen a year
SMR + CCS	Initiate decarbonisation through CCS of the grey hydrogen currently being produced	Scale-up decarbonisation through CCS of current grey hydrogen production units
SMALL SCALE:		
Regional/local electrolysis of water, maximum reliance on renewable energy	5 to 10 sites with a total installed capacity of 20 MW, representing 1.5 kilotons of green hydrogen a year	10 to 20 sites with a total installed capacity of 50 MW, representing 3.5 kilotons of green hydrogen a year
Alternative production technologies (local/regional)	Development and up-scaling of alternative production technologies, such as gasification from waste or syngas, or by pyrolysis 1 MW installed capacity of hydrogen panels, representing 36 kilotons of green hydrogen a year	Initial pilot projects related to alternative production technologies, such as gasification from waste or syngas, or by pyrolysis 10-15 MW installed capacity of hydrogen panels, representing 360-540 kilotons of green hydrogen a year

The target in Flanders should be set at a total installed capacity of **200 MW OF LARGE-SCALE ELECTROLYSIS CAPACITY**. That is the total amount produced by the *medium-scale* electrolysis projects in the four Flemish seaports (with each project producing several dozen MWs). This installed capacity ensures the production of at least 15 kilotons of green hydrogen a year[9], depending on the amount of renewable electricity available (at a competitive price).

> At 200 MW, Flanders would meet 3% of the European target, which is 6 GW by 2024.

[9] Assuming a load of 4200 hours. Increased production will be required for elevated use. This is also the assumption for other production targets based on electrolysis.

It is also in line with the Dutch targets, which should be at around 500 MW by that time. However, Dutch offshore wind capacity-related objectives are more ambitious than they are in Flanders. There was a total capacity of about 1 GW of wind turbines in Dutch waters in 2019, in contrast with the 11 GW targeted for 2030.[10]

Flanders/Belgium should reach 2,262 MW of offshore wind energy by 2020 and 'merely' aims to double that amount by 2030.[11] On land, Flanders had an installed capacity of 1.3 GW at the end of 2019 with a target of 2.5 GW by 2030.[12] Essentially, this means Flanders' electrolysis capacity is likely to remain restricted due to the limited supply of renewable energy.

> The amount of electricity required for the 200 MW electrolysis target is 0.8 TWh. Assuming an actual capacity of 15 TWh of green electricity in Flanders by 2025 (the 2030 target is 28.5 TWh), this implies the consumption of 5.3% of the green electricity capacity.

However, when there is enough or even a surplus of green energy, especially (offshore) wind energy, electrolysers ought to be fully mobilised to prevent curtailment as well and to support the cost-effective sustainability of the energy system.

A central electrolysis capacity of 200 MW by 2025 provides a springboard for continued scaling up to 2030's minimum target of 500 MW, provided that sufficient offtake can be guaranteed, for example in industry. This will lead to a combined green hydrogen production of at least 35 kilotons a year. This assumes the expansion of medium-scale projects to large-scale electrolysis of around 100 to 150 MW per plant.

In parallel to scaling up green hydrogen production, Flanders needs to focus on the **SUSTAINABILITY TRANSFORMATION OF CURRENT GREY HYDROGEN PRODUCTION** that is based on fossil fuels. To this end, CO_2 capture, a CO_2 liquefaction plant, interim storage of CO_2, and its cross-border transport by shipping and pipeline all need to be looked into. Transporting CO_2 across borders and storing it permanently in empty undersea gas fields calls for international partnerships.

> The goal is to start up a CCS plant by 2024 to produce low-carbon hydrogen at the current H_2 production plants with *steam methane reforming technology* that captures, transports, and stores CO_2.

By 2030, the goal is to have also commissioned new CCS plants that produce low-carbon hydrogen on all existing production units with SMR technology.

LOCAL AND REGIONAL HYDROGEN HUBS could have a capacity of 20 MW by 2025 or produce around 365 tonnes of renewable hydrogen a year. This type of project usually has a range of 1 to 5 MW and is contingent on the local availability of *renewables*. The broad outlines of the first generation of this kind of hub are emerging today, and 5 to 10 of these sites are predicted for 2025.

These hubs could have 50 MW of installed electrolysis capacity, or 3.5 tonnes of renewable hydrogen a year. As a result of lower investment costs and higher hydrogen demand, the number of sites in

[10] https://www.rijksoverheid.nl/onderwerpen/duurzame-energie/windenergie-op-zee
[11] https://www.belgianoffshoreplatform.be/en/
[12] Flemish Energy and Climate Plan 2021-2030, p.21

Flanders will increase to between 10 and 20. The power range remains unchanged at between 1 and 5 MW.

By 2025, potential **ALTERNATIVE FORMS OF PRODUCTION**, such as hydrogen by methane pyrolysis, gasification through waste or syngas will have been identified. By 2030, these forms of production will be mature enough to launch the first pilot projects to test how these technologies perform in real life. This does not correspond with any significant amount of renewable hydrogen production yet.

HYDROGEN PANELS will also be commercially available by 2025 with a pre-installed capacity of 1 MW, although this will admittedly still mainly pertain to (large) demo projects. They can then produce up to 36 tonnes of green hydrogen annually. This hydrogen can be used by a building/site to meet its heat and electricity demands. It stands to reason that the cost price of this green hydrogen will be competitively priced with that of green hydrogen produced via other methods.

The hydrogen panels will reach full maturity around 2030 and be used widely in the built environment, for example on homes, industrial buildings, in the agricultural sector, for transport, etc. The prediction is that within a decade, an installed capacity of 10-15 MW, representing 360 - 540 tonnes of green hydrogen a year, will have been achieved. Here too, the final price per kg will be commensurate with green hydrogen produced by other methods.

5.2 Import

5.2.1 Status and challenges

In addition to domestic sustainable hydrogen production, **IMPORTS OF** renewable hydrogen (or derived energy carriers) produced elsewhere will also be needed, preferably from regions with ideal solar and wind conditions. For the time being, there aren’t any concrete activities beyond conceptual ideas and studies.

Within the **HYDROGEN IMPORT COALITION**, a coalition between Deme, Engie, Exmar, Fluxys, the ports of Antwerp and Zeebrugge and The Hydrogen Industry Cluster, various EU import scenarios are currently being investigated. Research is also going into which carrier is best suited for transport by ship (liquid hydrogen, methanol, ammonia, etc.), which conversions, if any, need to take place, and in which applications the various carriers can be used.

INFRASTRUCTURE is an inherent aspect of any import story. Hydrogen or any derived molecule arriving by ship is unloaded at a suitable terminal. In Flanders, the Zeebrugge LNG terminal has experience with these operations. The Port of Antwerp is already currently involved in the import of various liquid and gaseous fuels. A pipeline linked to properly-equipped terminals must be installed to transport the molecules to the demand side. This underlying infrastructure is dealt with in the next chapter.

5.2.2 2025 – 2030 Objectives

IMPORT	2025 OBJECTIVES	2030 OBJECTIVES
Infrastructure	Roadmap for facilitating the infrastructure required to import hydrogen or derived molecules	Terminal infrastructure enabling the import of volumes of green hydrogen or derived molecules

	Start by constructing reception and transport infrastructure	
Import route set-up	First pilot project within a specific case	First volumes of hydrogen or derived molecules imported into Flemish ports
Partnerships	Conclude strategic partnerships with potential H_2 export regions	Consolidate strategic partnerships with potential H_2 export regions

A significant amount of footwork will need to be completed by 2025 to enable the import of hydrogen or derived molecules into Flanders. The initial exploratory study of technological challenges and business case studies needs to be followed up by a **DETAILED ROADMAP** that indicates which infrastructural interventions are required to make hydrogen import a reality. The roadmap must also clearly indicate where the receiving infrastructure could be implemented, taking current demand for hydrogen or derived molecules and the transport options in the hinterland via backbones into account.

Ideally, a roadmap of this kind should already be in place over the next few years so that a **PILOT PROJECT** can be up and running by 2025. Such a pilot project should be conducted within a well-defined case. That will entail the transport of hydrogen or derivatives from a foreign supply side by a dedicated vessel to a specific customer in Flanders via a *pilot hub* and local pipeline infrastructure. The result will be the acquisition of invaluable experience in terms of technology (shipping, delivery, and local transport) and safety and regulation.

Having a pilot project like this by 2025 will be crucial for substantiating import scenarios with practical experience.

- Industrial players are already currently looking at pertinent regions such as Iberia, South America, North Africa, and the Middle East for hydrogen and derivative imports. At this point, however, the federal and Flemish authorities also have a key role to play in establishing strategic partnerships with potential export countries.

Germany and the Netherlands are already a step ahead having agreed with Australia and Portugal respectively on the potential export of hydrogen or derivatives. Making this type of agreement is also one of their strategic hydrogen plan objectives. The Hydrogen Industry Cluster recommends that strategic partnerships in line with Flemish industrial connections be explored with potential export regions.

By 2030, the **STRUCTURAL IMPORT** of hydrogen and/or derived molecules such as methanol and ammonia into Flanders must be possible. And having a terminal infrastructure in place that can handle the import of large volumes is an essential precondition thereof. Converting current terminal infrastructure, such as the LNG terminal in Zeebrugge, scaling up the *pilot hubs* that will manifest over the next decade, or even constructing new infrastructure are all factors that need to be carefully considered.

The volumes anticipated by 2030 are still expected to be fairly modest and will primarily serve to help meet local hydrogen or different molecule demand. The type of **BACKBONE INFRASTRUCTURE** in place at the time will determine precisely which demand can be met. Simultaneously, this will need to be weighed against the inland production of sustainable hydrogen.

Strategic partnerships with export regions must be crystallised and consolidated as soon as the (structural) import of hydrogen or derived molecules becomes a legitimate reality. One option open to Flanders is the formation of trade agreements in which export regions guarantee specific volumes to the region of Flanders.

> Flanders' unique position in Europe with its plentiful seaports and underlying pipeline network, underscores its potential to develop into a European *import hub* for hydrogen and derived molecules.

5.3 Distribution and storage infrastructure

5.3.1 Status and challenges

Hydrogen is currently transported and distributed by **ROAD AND A PRIVATE PIPELINE NETWORK**. Tube trailers and HGVs delivering replaceable hydrogen cylinders currently constitute road transport of hydrogen. HGVs can transport several hundred kilogrammes of hydrogen at a time, and this may increase to up to 1,000 kilograms soon. Despite significant developments in more compact storage for lighter tanks, which will increase the efficiency of hydrogen transport by road, large volumes of hydrogen continue to require pipeline transport.

Around 45 years ago, Air Liquide installed an underground hydrogen pipeline network of approximately 900 km that connects large hydrogen production plants and hydrogen end-users active across various sectors throughout France, Belgium, and the Netherlands. The largest part of the pipeline network, some 600 kilometres, is located in Belgium, and functions as a hub for the port/industrial clusters of Antwerp, North Sea Port, Zeebrugge, and industrial customers in the Albert Canal industrial zone, as well as the environs of Feluy, Charleroi and Mons.

Hydrogen can be stored as a compressed gas or cryogenic liquid; however, there are inherent challenges to these forms of storage. For large-scale hydrogen storage, **UNDERGROUND ALTERNATIVES** such as salt mines or depleted gas fields must be used. Unfortunately, Flanders only has a meagre supply of this kind of large-scale hydrogen storage facility.

There is a potential alternative, however, in the underground natural gas storage facility in Loenhout, which is an aquifer, i.e., an underground water storage facility. Aquifers are geologically similar to depleted oil and gas fields, but their suitability must be confirmed in advance, and this on a *case-by-case* basis. The first simulation results for the Loenhout aquifer are promising, and there is a hydrogen-natural gas mixture injection test in the peripheral control shaft scheduled for 2021.

A pipeline network can, in one sense, also serve as a storage medium. In Belgium, the **CURRENT NATURAL GAS NETWORK'S** suitability for conversion to hydrogen-friendly gas pipelines is the subject of research; that includes exclusive transport of hydrogen and the gradual blending of hydrogen with natural gas. Studies show that only relatively limited infrastructural interventions are required to accomplish this. For the time being, however, there have not been any hydrogen pipeline conversions in Flanders, and blended transport remains untried.

Moreover, to determine whether or not to begin gradually blending, the potential impact (including additional costs) on the user related to the required changes must be assessed in advance.[13]

5.3.2 2025 – 2030 Objectives

DISTRIBUTION AND STORAGE	2025 OBJECTIVES	2030 OBJECTIVES
Natural gas network	Plan for future conversion of (parts of) the natural gas network to hydrogen. New natural gas infrastructure must be compatible with hydrogen and other green gases	
	Commence pilot projects blending hydrogen into the natural gas network and related adaptations to the natural gas network. Commence pilot project to convert natural gas pipeline to hydrogen	Conversion of first long-distance natural gas pipeline to hydrogen
New hydrogen infrastructure	Implementation of local open access backbones and first interconnections in port areas	Connect local port-backbones to the 'Flemish H_2 backbone'.

In principle, adding hydrogen to natural gas (**BLENDING**) is possible in the current infrastructure. However, the higher the percentage, the more infrastructural (and end user) adaptations will be required. In Belgium, the natural gas transmission system operator Fluxys has already conducted the studies needed on the technical potential of blending in the Belgian natural gas network or alternatively, fully converting natural gas pipelines to hydrogen. The infrastructure as it currently stands could transport up to 10% of the H_2 volume without any major modifications. In addition to the required steps to be taken, blending must always be considered in terms of usefulness and economic return due to a sustainable hydrogen supply that remains limited.

The closer it gets to 2025, the more pressing it will become to transform the study into an **ACTION PLAN** for introducing hydrogen into the natural gas network. That should be complemented by pilot blending projects in the natural gas network while keeping in mind that the volumes of hydrogen in the natural gas network will remain relatively negligible. Any new or upgraded natural gas infrastructure must also be 'future-proof' from now on, i.e., capable of transporting hydrogen and other green gases.

A full conversion of the natural gas pipelines to hydrogen will also require **PRACTICAL EXPERIENCE**, to include an inventory of how hydrogen reacts with various materials in the pipelines. To this end, one option in Flanders would be to use natural gas pipelines that have become obsolete or can be switched

[13] See e.g., CEFIC (2019) position on hydrogen https://cefic.org/app/uploads/2019/11/Cefic-position-on-Hydrogen-1.pdf

off. Ideally, preparations for linking (planned) production locations to centres of demand should have been made in advance.

NEW, OPEN-ACCESS, hydrogen-compatible **PIPELINES** will also be required to complement reuse of the current pipeline infrastructure. In the short term, constructing **LOCAL BACKBONES** in the port areas of Ostend, North Sea Port, Antwerp, and Zeebrugge must be addressed first. The first steps towards future local backbone interconnections will also need to be taken.

The projected length of a local backbone like this for the Port of Antwerp is 30 kilometres. A determination has been made at the North Sea Port, that 12 chemical companies could be connected via a 65 km hydrogen pipeline network. In the Port of Zeebrugge, a local network would cover from around 15 to 25 km. Moreover, Zeebrugge can play a pivotal role in a combined offshore wind – hydrogen – liquid hydrogen terminal. Should this come to pass, a local hydrogen pipeline network would need to be installed, e.g., within the context of a future import scenario.

> As of 2030, the logical 'next step' is to connect the (new) local infrastructure to a **FLEMISH HYDROGEN BACKBONE**. This approximately 100-km connection must provide all interested market operators with access on equal terms,

This will make it possible to connect the planned hydrogen plants with an industrial demand side. However, the supply and demand sides need to be coordinated. To an extent, this new network complements Air Liquide's current private hydrogen network. Nevertheless, it must be kept in mind that the current hydrogen infrastructure has been financed and constructed privately and is also run by a private entity as part of its business operations.

By 2030, the first long-distance sections could be converted from natural gas to hydrogen only. This objective harmonises with the European hydrogen backbone plan, in which eleven European natural gas infrastructure companies, to include Fluxys Belgium, have developed a plan for a dedicated hydrogen transport infrastructure.[14]

From a European perspective, Flanders plays a key role due to its well-developed natural gas infrastructure, as well as its connections with seaports and key neighbouring countries. In Flanders/Belgium, an initial conversion project between the Ghent and Liège industrial clusters is a good option and could include a connection to France.

5.4 Hydrogen in industry

5.4.1 Status and challenges

In Flanders, there is an estimated **200 KILOTONS OF (GREY) HYDROGEN** produced annually from natural gas, which goes on to be used as a **RAW MATERIAL** in several industrial sectors. For example, hydrogen is used to refine fossil fuels for cracking or desulphurisation of fuels, is employed in the steel industry to anneal steel, and functions as a molecular building block in chemistry.

The fossil fuel-based hydrogen currently used in industrial processes can gradually be replaced by equivalent sustainable hydrogen. Around 100 kilotons consumed annually by industry is already available today as low-carbon residual hydrogen. Initiating the decarbonisation of current SMR

[14] https://www.fluxys.com/en/news/fluxys-belgium/2020/200717_news_european_hydrogen_backbone

technology production units in 2024 at SMR-based plants is an objective that was addressed earlier on in this paper; this objective also proposes that the current SMR-based hydrogen production units be fully connected to CCS installations by 2030.

Moreover, various **NEW APPLICATIONS AND PROCESSES**, in which hydrogen could positively contribute to going climate-neutral, are also within the realm of possibility. In the steel industry, hydrogen can be used to produce direct reduced iron (DRI, or sponge iron) or partially replace cokes in blast furnaces.

Hydrogen can also be used to produce primary products from chemicals and synthetic fuels in which hydrogen is combined with recycled CO_2 from industrial sources (carbon capture and utilisation - CCU) or with CO_2 derived from the air in the long term (direct air capture – DAC).

Hydrogen can also function as building blocks for ammonia, methanol, ethylene, propylene, chlorine and the aromatics benzene, toluene and xylene. Production of these substances is currently based on fossil natural gas or oil and could be replaced by bio-based raw materials or recycled CO_2 and hydrogen.

Hydrogen can also meet the **ELECTRICITY AND/OR HEAT DEMANDS** of industry. It could be used as a substitute for natural gas in processes that require high temperatures (medium and high-level heat) or where the use of residual heat or electrification is not an option. When hydrogen is burned, high temperatures can be reached without producing CO_2 emissions. Methods and principles such as CHP, turbines, engines, and fuel cells, also make it possible to meet (high power) electricity demands.

Right now, the biggest barrier to replacing grey hydrogen with renewable hydrogen is the cost of production equipment (electrolysis) and raw material (electricity), compared to the cost of the current supply of fossil fuel-based hydrogen.

5.4.2 2025 – 2030 Objectives

H_2 IN INDUSTRY	2025 OBJECTIVES	2030 OBJECTIVES
Current application with H_2 as a raw material	Demand for sustainable H_2 is high enough to ensure optimal use of production capacity	Demand for sustainable H_2 is high enough to ensure optimal use of production capacity
New applications	Pilot project on synthetic raw materials based on sustainable hydrogen	Structural production of synthetic raw materials using sustainable hydrogen
	A pilot project in the steel industry	10% blend of H_2 in steel industry blast furnaces
Industrial heating demand	Pilot project industrial heat demand	Initial high-temperature applications
Industrial electricity demand	New turbines and engines available on the market suitable for an injection of up to 50% H_2 in natural gas	New industrial application turbines and engines that are 100% H_2 compatible are available

The closer 2025 (and 2030) gets, the more crucial it is to **BOOST INDUSTRIAL DEMAND** for hydrogen as a raw material. The price of green and blue hydrogen is significantly higher than the grey hydrogen currently in use. While that gap will narrow in the coming years, it will not diminish entirely.

Current and future hydrogen users also bear responsibility in the transition to more sustainable hydrogen. Provided there is sufficient demand, the production capacity of sustainable hydrogen can be optimised in the future, which could result in further scaling up and cost reductions.

For new hydrogen applications in industry, such as feedstock for sustainable chemistry or synthetic fuels, The Hydrogen Industry Cluster aims to commission the first **DEMO PROJECTS** by 2025, which could include sustainable methanol production, for instance.

By 2025, the **STEEL INDUSTRY** can also anticipate a pilot project. A percentage of coke oven gas converted into hydrogen-rich gas during reforming can be re-injected into the blast furnaces, which will reduce blast furnace CO_2 emissions by around 10%. The first project in which hydrogen is injected into the blast furnace in substantial volumes could take place in the coming years and reaching the 10% limit could happen by 2030.

From a technical perspective, hydrogen could contribute to providing industry with **SUSTAINABLE HEAT AND ELECTRICITY**. Turbine and CHP technology capable of partially or fully burning hydrogen, for instance, are under development and, in some cases, are even already available; however, the cost of the hydrogen remains prohibitively expensive. Were H_2 is to be *blended* into the natural gas network on a large scale, then it would automatically be incorporated in these applications.

Objectives related to the technical possibilities of working with hydrogen-powered turbines and engines should not be assessed in terms of market *uptake*, but rather in terms of supply. To this end, pilot applications are not expected until 2030. The turbine suppliers' sector is committed to equipping their products for 20% blending by 2020 and 100% by 2030.[15]

> Hydrogen's priority role in industry focuses on raw material use rather than energy applications.

5.5 Hydrogen in transport

5.5.1 Status and challenges

This paper has already touched on the fact that the first hydrogen-powered vehicles and H_2 service stations have already been commissioned. Four additional **HYDROGEN FILLING STATIONS** are scheduled to launch in Flanders in 2021: DATS 24 (Colruyt Group) will open another three filling stations in Wilrijk, Erpe-Mere and Haasrode, while CMB will launch a filling station in Antwerp.

DEMO PROJECTS with hydrogen-powered HGVs and waste collection vehicles are currently in the start-up phase. A 27 and 44-tonne hydrogen-powered HGV – converted by VDL – is currently being tested in Flanders and will refuel at the DATS 24 filling station (Colruyt Group) in Halle. Two hydrogen-powered waste collection vehicles for the city of Antwerp, built by E-Trucks Europe, are scheduled to use the new filling station in Wilrijk (also DATS 24).

[15] EUTurbines, 'Gas Turbines: Driving the transition to renewable-gas power generation,' 2019, https://powertheeu.eu/

Purchasing hydrogen-powered vehicles that run on **FUEL CELLS** remains expensive compared to the purchase of a battery-electric equivalent, not to mention models that run fossil fuels. Right from the start, the price of an HGV or bus will be two to three times higher than that of a diesel, and hydrogen-powered cars correspond with the price tag associated with high-end electric cars. Hydrogen's pump price, currently at around €10 per kg, leads to a TCO that exceeds that of zero-emission alternatives.

In addition to developments in fuel cell vehicles, hydrogen-powered **INTERNAL COMBUSTION ENGINES** are also being researched. Pure hydrogen is one option, while a dual fuel solution, blending hydrogen and diesel, is another. This concerns a tried and tested technology with lower purchase costs. Pure hydrogen-powered combustion engines are almost zero-emission and retrofitted dual-fuel vehicles benefit from significantly reduced emissions. First and foremost, this should be regarded as a viable technology in a gradual hydrogen transition. BeHydro, a joint venture between Anglo Belgian Corporation and CMB, focuses on this technology for both (road) vehicles and ships.

SCALING UP THE PRODUCTION of such vehicles could reduce costs considerably. At the same time, headway must be made towards infrastructure that matches the scale-up in production. That will allow the pump price of hydrogen to drop as soon as sustainable hydrogen production hits cruising speed. By investing in these three processes, hydrogen-powered vehicles should become a viable alternative to battery-electric equivalents. Hydrogen means rapid refuelling and good range, giving it significant advantages, especially in the heavy-duty and/or long-distance segment where electrification is a challenge. Vehicle manufacturers have also noticed that the potential of hydrogen for intensive and long-distance applications only continues to grow.

5.5.2 2025 – 2030 Objectives

H_2 IN TRANSPORT	2025 OBJECTIVES	2030 OBJECTIVES
Filling stations	>20 HRS (350 and 700 bar)	>100 HRS (350 and 700 bar)[16]
Heavy duty	>300 HGVs and vans	>2,500 HGVs and vans
	>50 buses (3 HRS)	>250 buses (10 HRS)
	>25 waste collection vehicles	>200 waste collection vehicles
	First H_2-powered (or derived) inland vessels 2 multi-fuel hubs	>25 H_2-powered (or derived) inland vessels 7 multi-fuel hubs
	Study first train route	Implement first train route (1 HRS)
	Construction and agricultural vehicles demo project	>100 construction and agricultural vehicles
	>200 logistics equipment	>500 logistics equipment
Passenger cars	>1,000	>15,000

[16] Potentially including a few liquid hydrogen filling stations should the heavy-duty market focuse on this in the future.

A **CORRESPONDING REFUELLING INFRASTRUCTURE** (HRS) can support the roll-out of hydrogen-powered vehicles. The Hydrogen Industry Cluster targets the installation of at least 20 filling stations by 2025. Smart spatial planning can ensure that the distance between filling stations in Flanders doesn't exceed 20 kilometres. It is essential that 700 bar (for passenger cars) and 350 bar (for heavier vehicles) both be made available.

Considering a scale up to at least 100 hydrogen filling stations by 2030 should be feasible. That would put Flanders on the same page with its neighbour, the Netherlands, which is aiming for 50 stations by 2025. Either way, infrastructure growth will need to serve a growing fleet of hydrogen-powered vehicles. The **HEAVY AND/OR LONG-DISTANCE TRANSPORT** segment holds the greatest potential. This opinion enjoys broad consensus in light of the complementarity with battery electric vehicles, which are primarily good for driving shorter distances and powering lighter forms of transport.

> As far as applications go, HGVs of every kind offer the most promise. To facilitate a market launch, refuelling infrastructure at logistically strategic locations must be in place first (or in tandem). Once again, port areas are first in line.

In view of project announcements, a projected minimum of 300 HGVs on the road by 2025 is realistic. Hydrogen delivery vans – another promising application, albeit at a less mature stage in product development – may also be expected by that time.

- Another application with significant potential is hydrogen-powered buses, which benefit from a high degree of technological maturity. What's more, Flanders is home to actors that belong to the international apex of hydrogen-powered bus development. These buses are particularly well-suited to zero-emission regional transport, in contrast with battery-electric buses, which are more efficient in an urban setting.

De Lijn's focus, until now, remains exclusively on battery-electric buses. As a result, The Hydrogen Industry Cluster hopes to shift that focus to zero-emission buses, on a playing field that is level for all technologies. Battery electric buses are not sufficiently equipped to handle intensive use and long routes. On a similar note, the electrical charging infrastructure available in large cities often leaves much to be desired when it comes to supplying battery-electric buses with enough power.

Flanders should aim to implement a handful of *flagship* projects, each with their own refuelling infrastructure and a few dozen buses by 2025. Experience gained from these projects will open the right doors to scale up by 2030, at which point hydrogen-powered buses will form an essential part of the zero-emission fleet. Specifically, The Hydrogen Industry Cluster aims to have 250 buses on the road, refuelling at the ten filling stations in Flanders.

Another strategic niche fleet is **WASTE COLLECTION VEHICLES**, and here too, Flanders is home to several *key players*. To this end, local and intercommunal authorities have a decisive role to play in terms of their willingness to support the roll-out of hydrogen-powered waste collection vehicles. Moreover, the local authorities, as the *launching customers*, will also need to incorporate their own climate goals. The roll-out of waste collection vehicles will go hand in hand with the available refuelling infrastructure. The Hydrogen Industry Cluster aims to have at least 25 waste collection vehicles in Flanders by 2025 and 200 by 2030.

Hydrogen will also play a pivotal role in **SHIPPING** as a (near) zero-emission fuel. From a technological perspective, the debate over which form of hydrogen or derivative molecule is the best match for powering ships is in full swing. The best propulsion system (fuel cells or internal combustion engine) for the required workload is also still under discussion. There is a good likelihood that pure hydrogen will be used in inland navigation first, while liquid fuels such as ammonia and methanol will be used for maritime shipping instead. Flanders has several key players in relevant fields, which means that application testing should take priority.

As 2025 approaches, one of the first steps to be taken is the conversion of the first **INLAND VESSELS** to a hydrogen propulsion system. These could then be deployed on a route equipped with a number of (multi-fuel) bunker facilities. There should be more clarity about the most feasible and efficient (inland) vessel fuel and propulsion system after 2025. The 2030 target for Flemish inland waterways is to have a fleet of at least 25 inland vessels that can refuel at seven multi-fuel hubs distributed throughout Belgium.

Where the railways are concerned, **HYDROGEN TRAINS** could offer a sustainable alternative to diesel trains. Germany started its first hydrogen-powered passenger service in 2018 and is looking to expand, and the Netherlands has already run a series of successful tests. Due to the high degree of electrification of the Belgian railway lines, hydrogen trains would only function as a niche application. However, specific freight lines that continue to rely on diesel trains, in port areas, for example, may be an exception to this rule. A strategic route could be mapped out by 2025, where demonstration tests could be run, for example by mobile delivery. In 2030, this could be transformed into a fixed route with *dedicated* refuelling infrastructure.

LOGISTICS EQUIPMENT is yet another promising application. Light forklift trucks that run on fuel cells are already a mature application, and there are 50,000 units worldwide, with several dozen in Flanders. Through rigorous use, these may rival their battery-electric counterparts. For heavier logistics and construction equipment, initial hydrogen-related developments are already underway, including hydrogen combustion conversion projects and fuel cell prototype demonstrations.

Ports are an ideal environment for rolling out heavy-duty logistics applications, which can be linked to local applications such as port handling equipment or (small) vessels. Small logistics equipment such as forklift trucks and stackers can continue to be scaled up. The target for 2030 is at least 100 construction and agricultural vehicles and 500 pieces of logistics equipment of various kinds.

Lastly, **PASSENGER CARS** are the hottest tech innovation in the realm of hydrogen-powered vehicles, and they are commercially available. However, competition is fierce in this segment due to battery-electric vehicles. Hydrogen-powered cars have an edge though because their range is wider, and they refuel faster. These characteristics make them perfect for (intensive-use) niche fleets such as taxis. What’s more, they will always appeal to a (limited) segment of the private and corporate zero-emission fleet. The number of cars will increase the more filling stations there are, with a minimum of 1,000 in 2025 up to 15,000 in 2030.

5.6 Hydrogen in the built environment

5.6.1 Status and challenges

Hydrogen as a means of making the heat and electricity demand in the built environment more sustainable is a topic that has been largely neglected. That is largely due to the existence of alternatives readily available on the market, such as solar panels, heat pumps, geothermal energy, solar boilers, heat networks, home batteries, biomass, etc. When it comes to heating, we still largely rely on natural gas. Until now, the main focus of sustainable gas has been biogas.

However, hydrogen produced from renewable sources is also a legitimate means of sustainably meeting heat and electricity demand. **HYDROGEN BLENDING** in the current natural gas network would be a logical first step towards supplying that hydrogen. An injection of up to 10% is possible without having to make any radical modifications to infrastructure or end-user facilities. That said, whether or not this course of action is advisable still requires further study.

Hydrogen could also be transformed into **SYNTHETIC METHANE**, which has the same chemical properties as natural gas. Unfortunately, this is a costly process. The last alternative would be to **FULLY CONVERT** the existing natural gas network and require user applications to be 100% hydrogen-powered. That would require a complete overhaul of the network's infrastructure and end user devices.

Technologies such as hydrogen-fuelled boilers and CHPs (combustion and fuel cells) make it possible to transition existing buildings from natural gas to hydrogen. With CHP technology, all kinds of features in and around buildings can be linked with maximum efficiency. For example, electricity can be supplied at the same time the building is being heated, e.g., charging electric vehicles locally. This could be connected to absorption cooling, for example in office buildings and data centres.

A hydrogen gas network also creates opportunities for hydrogen prosumers, who produce green hydrogen locally from solar energy and inject it into the network, much like solar panel ownership works today.

In addition to centrally supplied hydrogen via the gas network, **HYDROGEN COULD ALSO BE PRODUCED LOCALLY** as part of domestic energy production; this could be used, for example, to (partially) bridge the winter. There are systems currently being developed to this end, which can be used per building (complex) or by district. The biggest hurdle, at present, is identifying affordable and compact hydrogen storage solutions.

> Pilot project test results and studies on how and where hydrogen fits within the built environment's energy transition will provide crucial input for future developments.

5.6.2 2025 – 2030 Objectives

H_2 IN THE BUILT ENVIRONMENT	2025 OBJECTIVES	2030 OBJECTIVES
Replacement of natural gas and local production/storage	Roadmap for potential hydrogen applications in the built environment	

	Hydrogen applications in the built environment pilot projects take off	Scaling up of hydrogen applications in the built environment
	Availability of new heating units compatible with a 20% hydrogen blend	Availability of new heating units compatible with a 50% hydrogen blend
	Plant > 200 (µ) hydrogen-fuelled CHPs	Plant > 5,000 (µ) hydrogen-fuelled CHPs

Technological opportunities, studies, and test results will need to be assembled for review soon. That way a **ROADMAP** can be created on the usability of hydrogen applications in Flanders' built environment. This roadmap will need to be reinforced with a few specific demonstration projects in the built environment, analogous to a few Dutch examples. This will include targeting various technologies in multiple case studies.

The roadmap and initial test results could pave the way for a **STRATEGIC VISION FOR HYDROGEN'S ROLE IN THE BUILT ENVIRONMENT'S ENERGY TRANSITION** at the Flemish level by 2030. By that time, (pilot) projects should have reached maturity and Flanders is likely to have five concrete (test) case studies available. Here, too, the use of different technologies in different situations is preferable.

In addition to local hydrogen production, e.g., via electrolysis or hydrogen panels, a centralised hydrogen supply via a (natural gas) network, either blended or pure, could represent another way forward. Gas dependency will remain in future, but that gas will be green if planned properly. Should a decision be made to blend hydrogen with natural gas, then all devices connected to the network must be equipped to process this blending.

Specific objectives related to the installation of **(MICRO) CHPs** (combustion or fuel cell) for residential applications in Flanders are being drawn up; these draw on the available technological expertise and developments at the European level.[17] This concerns both CHPs with local storage and connection to a future H_2 network or a natural gas network injected with hydrogen.

5.7 H_2 in the power sector

5.7.1 Status and challenges

Flexible electricity generation capacity is essential to the future energy supply. Due to their irregular production profiles, solar and wind energy – as the main renewable energy sources – must be supplemented by other mechanisms and sources.

This can partially be accomplished with the demand-side response and battery storage, but these alone won't suffice. The current context anticipates a need for flexible gas power stations to meet peak demand, and the Planning Bureau projects that even a third of electricity will still be generated by thermal power stations[18] in 2050.

[17] See, for example: Hydrogen Europe, 'Strategic Research and Innovation Agenda' (final draft), 2020, p.114-115.

[18] https://www.plan.be/publications/publication-2056-en-fuel_for_the_future_more_molecules_deep_electrification_of_belgium_s_energy_system_by_2050

The Planning Bureau is counting heavily on hydrogen, either produced locally from electrolysis or imported, to supply these thermal power stations in 2050.

The closure of nuclear power plants by 2025 has recently been reconfirmed and automatically gives rise to a need for more thermal power plants in the short term. According to most conventional estimates, five new large gas power stations with a total capacity of 3.9 GW will be required.[19] How much these power plants will be used depends strongly on how electricity demand and production evolve, consequently limiting the predictability of the business case.

These new plants, scheduled to come online in 2025, cannot fully rely on hydrogen because the technology will only be available as of 2030 (see above). The high cost price of H_2 fuel and the demand for large volumes also render the situation untenable. Blending hydrogen with natural gas, on the other hand, is more within reach. Current turbine technology and a few modifications to the power plants would make this a technologically feasible option. However, economic parameters will factor into that success as well. Initial applications, for example, could rely on residual hydrogen. It is only towards 2040 that power-to-H2-to-power (P2H2P) will genuinely begin to play a major role, as a result of its contribution to the energy system's flexibility.

At the end of the day, this means that there are no hydrogen applications scheduled for the power sector in the immediate future. Nevertheless, technological opportunities must become (or have become) available so that the power sector can eventually go that route. Trade-offs with other CO_2-reducing technologies and fuels (e.g., synthetic methane) will also weigh into how H_2 use evolves. It makes sense for the development of the H_2 and CO_2 backbones to take these plants into account.

The EU will also steer the sustainability trajectory of these future thermal power plants and the power sector in general. In addition to the 2030 and 2050 CO_2 emission reduction targets, there are also incentives being developed to promote investment in sustainable technology.

To attract investors to Belgium's future gas power stations on the one hand, and to realise a sustainable future on the other, low emissions must be guaranteed, and power stations must run on low-carbon fuels, especially hydrogen (or derived carriers).

5.7.2 2025 – 2030 Objectives

H_2 IN THE POWER SECTOR	2025 OBJECTIVES	2030 OBJECTIVES
	Turbines are available that are compatible with a 50% H_2 injection in the gas mix	Turbines are available that are 100% hydrogen compatible

5.8 Hydrogen value chain in Flanders 2025-2030 projection

The aforementioned 2025 and 2030 projections for the different links in the hydrogen value chain are graphically summarised in the two figures below:

[19] https://www.elia.be/-/media/project/elia/elia-site/company/publication/studies-and-reports/studies/13082019adequacy-and-flexibility-study_en.pdf

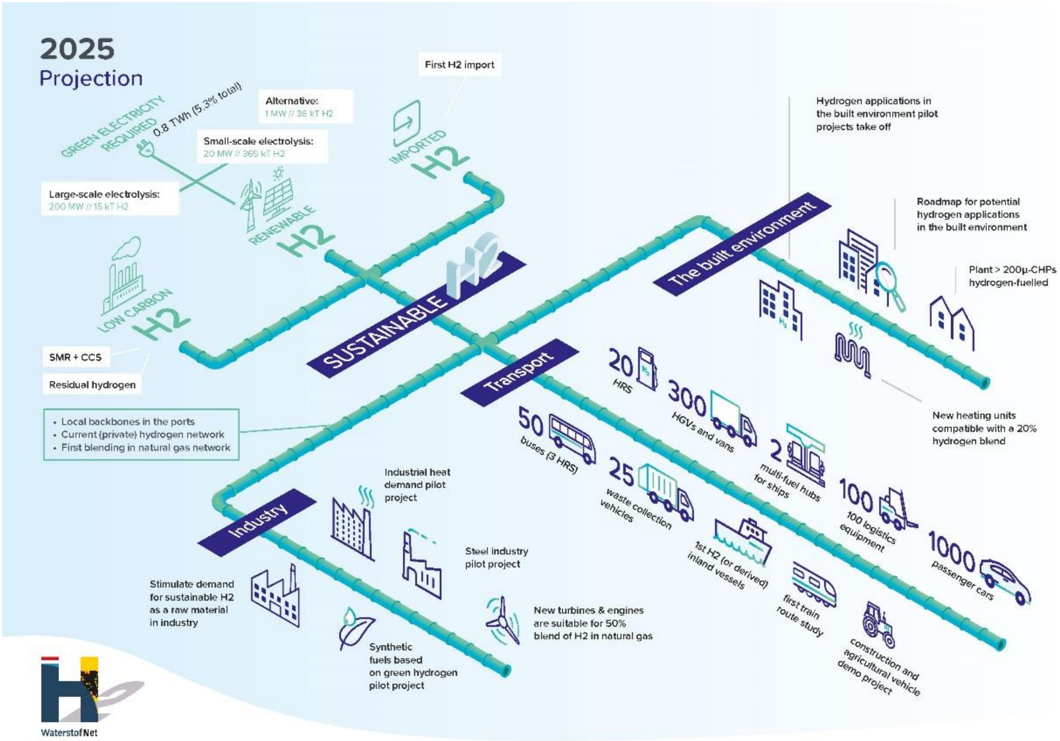

Figure 7: The Hydrogen Industry Cluster member targets for 2025

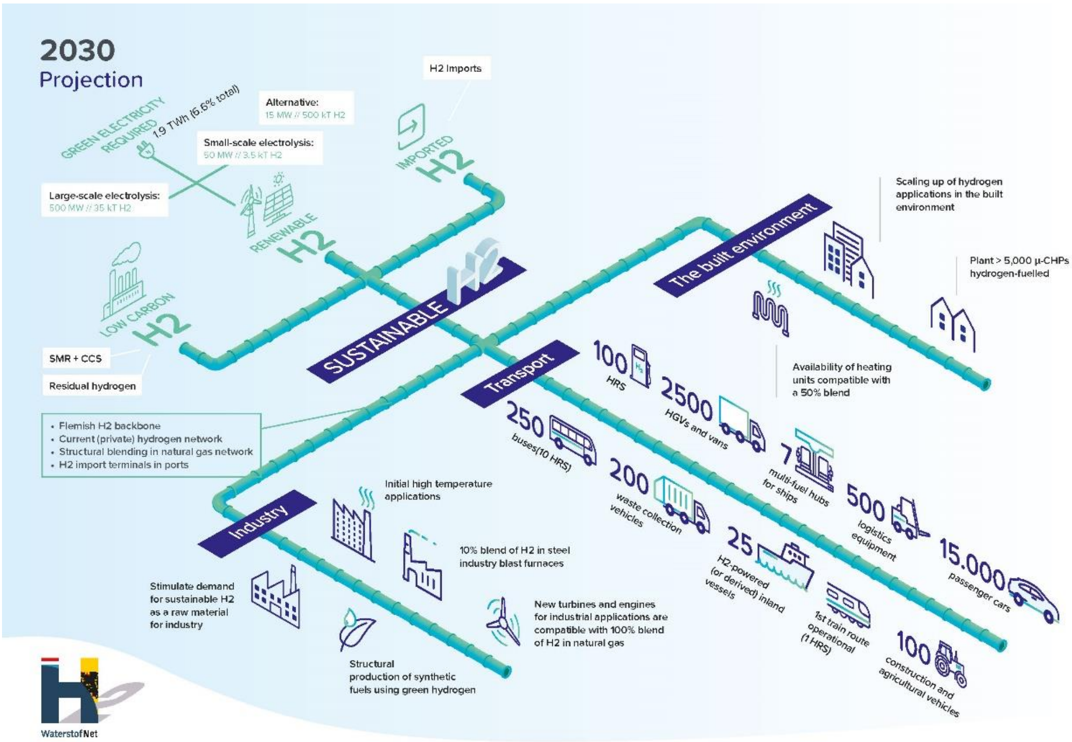

Figure 8: The Hydrogen Industry Cluster member targets for 2030

It is worth underlining that these projections are based on specific company targets. As a result, they can be seen as realistic objectives, provided the requisite framework and support from various public authorities are available.

5.9 2020: projects in the pipeline

To prove that the roadmap above represents a realistic industrial hydrogen development policy strategy, a **SNAPSHOT** of the situation in 2020 in terms of planned and implemented hydrogen projects is provided.

Four additional filling stations in Flanders are planned for 2021 to 2022. A tugboat powered by hydrogen (and diesel) will operate in the Port of Antwerp from 2022 onwards. In the port areas, the introduction of hydrogen-powered HGVs along with the related infrastructure is in the works.

Various initiatives are being developed in the area of large-scale electrolysis projects, particularly in the ports. In total, approximately 150 MW of capacity will be announced in 2025, with a scale up to 1 GW by 2030. New small-scale electrolysis projects are starting to take shape, e.g., in Zelzate and Genk.

Electrolyser construction projects are also in the pipeline, which will inject green H_2 into the existing network as soon as a market for these applications exists and subject to the requisite public support, of course.

In the built environment, hydrogen panel, CHP, and residential production and storage application demo projects have been scheduled.

The Port of Antwerp is a special point of focus, where research into constructing an infrastructure to facilitate hydrogen imports is underway, as well as studies into creating a CO_2 backbone to transport this to Rotterdam as part of various CCS projects.

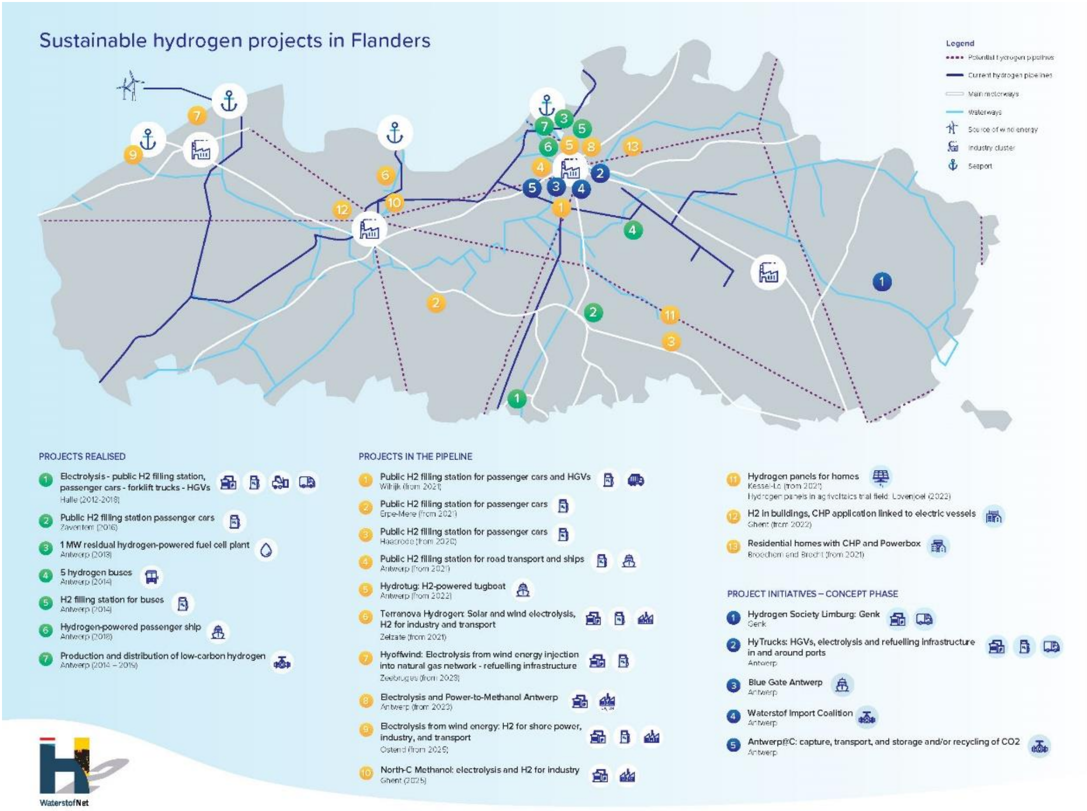

Figure 9: planned and implemented hydrogen projects in Flanders (2025)

6 Research and innovation

Testing and implementation of technology currently being developed by Flemish companies is only part of the picture. Prioritisation and development of **LONG-TERM INNOVATIONS** in Flemish knowledge institutions are also key. Multiple steps remain to be taken along the entire hydrogen value chain before the EU hydrogen strategy can be realised. And basic research is at the heart of developing GW-scale capable electrolysis, efficient storage and transport of large volumes of hydrogen, and making new hydrogen-based chemical processes accessible to industry.

- Several different research groups in Flanders are active in fields that are relevant to the continued roll-out of hydrogen technology; however, that research is currently anything but streamlined. To complicate matters more, a clear, structural link between knowledge institution activities and technology company developments remains absent.

By monitoring and consolidating these activities in a '**FLEMISH HYDROGEN PROGRAMME**', more targeted research would be possible, and several spearheads could be identified for Flanders to focus on, thus enabling it to play a key role in the European context. An integrated approach, in which knowledge institutions and companies closely partner, will also automatically lead to the education and training of essential experts, who, on graduating from Flemish knowledge institutions, can move on to share their expertise with companies.

The announcement of a specific **IMPULSE PROGRAMME** on the hydrogen research agenda in the Flemish Hydrogen Policy Strategy 'European frontrunner through sustainable innovation' represents the first step towards a Flemish hydrogen research programme of this kind. Members of The Hydrogen Industry Cluster would like to contribute to the design of such an impulse programme and would be pleased to partner in its implementation.

The table below provides a (non-exhaustive) overview of potential research topics in which several knowledge institutions in Flanders already possess expertise related to specific links in the hydrogen value chain:

Topic/application	Research topics	Flemish knowledge institution expertise
Hydrogen production	Electrolysis→ scaling up, cost reduction, efficiency Hydrogen panels → Industrialisation, system development, further integration of PV/H_2 production New concepts → H_2 from waste or syngas, etc. Next Generation Electrolyser	Membranes Electrode materials Catalysts Direct conversion PV -> H_2 Nanotechnology and Membrane Electrode Assemblies
Transport & Distribution	H_2 in the natural gas network: → Natural gas network and storage analysis, material testing	Steel/hydrogen interaction
Storage	Storage tank scale-up Compact storage in large terminals Underground storage	Pressure indicators and gas dynamics in large tanks LH_2 storage; insulation and boil-offs Storage of densified cryogenic fluids ('slush') Geology and stability
Vehicles, ships, and aircraft	Compact H_2 storage in vehicles/ships Engines powered by H_2, methanol, ammonia, kerosene Compact liquid hydrogen fuel tanks (LH_2)	LOHC storage H_2, methanol, ammonia, kerosene combustion engines LH_2 fluid dynamics in fuel tanks and fuel supply systems
Heat and electric power	Fuel cells, engines and turbines, CHP	Combustion processes: numerical modelling and experimental testing
Industry	CCU/e-fuels production	Synthesis of H_2 (+ CO_2) into chemical feedstock (methanol, ammonia, etc.) Catalysts

7 Recommendations for Flemish and federal legislation and policy

Production and consumption of renewable and low-carbon hydrogen are not economically feasible yet. Nearly every fossil-fuel-powered application is still considerably cheaper, and the contribution of CO_2 emissions to the cost price remains extremely limited. For that reason, a handful of stimulus measures are needed to introduce hydrogen in several critical sectors and initiate scale-ups.

The following chapter provides an overview of The Hydrogen Industry Cluster's key recommendations to the administration on maximising opportunities in Flanders to develop hydrogen and derived energy carriers. It also addresses these different policy measures in greater detail and relates them to the (predicted) relevant EU directives.

7.1 Production of hydrogen and hydrogen-based energy derivatives

Sustainable hydrogen currently costs significantly more than grey hydrogen, due to high production-related investment costs and the cost of electricity. For hydrogen's initial roll-out, lowering the costs of sustainable hydrogen production is essential, and necessarily entails the provision of an equivalent policy framework and the right tools. Recommended policy measures include:

- (Partial) exemption from electricity-related taxes/charges for hydrogen production
- Continued implementation of the Guarantees of Origin system in Flanders, expansion to low-carbon hydrogen and e-fuels, and maximum harmonisation of the GO instrument with the other regions and the Member States. A uniform EU system is the end goal.
- Introduction of differentiated taxation of energy carriers based on greenhouse gas intensity
- Access to sufficient, affordable, and reliable energy

7.2 Distribution and storage infrastructure

To connect large-scale hydrogen production and import with end users an extensive hydrogen network must be present. Part of the current gas network can be employed to accomplish this. The only hydrogen-capable network in Belgium at present is one that belongs to the private industrial gas sector, which is geared specifically to different users in terms of volume and quality. Blending hydrogen into the existing natural gas network should mark the launch of the transition period.

Key recommendations at this stage are:

- Development of a legislative framework for blending hydrogen into the existing natural gas network, supported by feed-in tariffs (provided this is a relevant transitional method)

- Development of legislation that facilitates the development of an open-access network for hydrogen and CO_2. Nevertheless, it must be kept in mind that the current hydrogen infrastructure has been financed and constructed privately and is also run by private entities as part of their business operations.

7.3 Hydrogen in industry

Today, major hydrogen consumers in the large industrial clusters can obtain grey hydrogen at cut-rate prices. Several Green Deal initiatives have been announced at the EU level to promote sustainable raw material use; however, implementation will not happen overnight. Given the international nature of industrial operations, closely monitoring competition must be prioritised. That way essential investments can continue to be made in Europe and *carbon leakage* can be prevented.

The policy recommendations below reflect this:

- Implementation of low carbon technologies is contingent on its competitive edge vis-a-vis current technologies. Cost reduction of low carbon technologies depends, on the one hand, on prioritising and investing in research and innovation, while on the other, it calls for the exploration of new, possibly temporary instruments to assist the transition from demonstration projects to large-scale implementation.

- Research new instruments (such as Carbon Contracts for Difference) to support new, non-competitive 'low-carbon' technologies for initial large-scale implementation.

In the short term, to get the first large-scale hydrogen projects up and running, (temporary) support schemes will be needed.

The policy recommendations for that period include:

- Developing a targeted Flemish investment aid framework for pilot projects on an industrial scale that takes the initial lower cost efficiency of these installations into account

- Incentivising companies by expanding the 'Ecology Premium Plus' to cover non-transport applications by adding new items to the fixed technology list (e.g., electrolysis, fuel cells that recover heat, etc.)

7.4 Hydrogen in transport

Hydrogen can be used in transport in different sectors (passenger transport, public transport, road and inland waterway freight transport) and through different technologies (vehicles or ships powered by fuel cells or combustion engines). Derived liquid fuels can also be used as 'e-fuels', which could be blended with fossil fuels in a transitional period (cf. today's biofuel blending), or they could be used as an alternative fuel (non-blended).

The policy recommendations below pertain to transport:

- Develop a plan in consultation with the sector (filling station operators, transport federations such as Febetra, Febiac, ACEA, etc, vehicle manufacturers, etc.) for the roll-out of a refuelling infrastructure network that provides sufficient coverage for Flanders, at minimum. This must include locations for H_2 generation, transport and storage.

- Exempt zero-emission heavy-duty transport from taxes and charges, e.g., by lowering or lifting tolls.

- Explicitly include hydrogen-powered buses in De Lijn's long-term plans as an alternative to regional transport.

- Explicitly include RFNBOs[20] in the Belgian fuel law, as stipulated by the REDII. That could include liquid, gaseous fuels, or pure hydrogen. Hydrogen's development and the development of derived energy carriers – in addition to biofuels and electricity – require a level playing field.

- Support inland navigation pilot projects and perpetuate an active role in CCR to develop the general legal framework on inland navigation alternative fuels (especially H_2 and methanol) and fuel cells/combustion engines.

- Exempt hydrogen-powered mobility applications from excise duty until the initially high costs of hydrogen can be bridged.

7.5 Hydrogen in the built environment

While hydrogen use in buildings may still require more study compared to other energy-efficient and/or CO_2 neutral solutions, it is clear that the full electrification of the build environment's heat and power supply will not be feasible in a carbon-neutral society. In this regard, there is a distinct lack of a legal hydrogen framework, especially where safety standards are concerned. Consequently, the following recommendations are proposed:

- Support pilot projects required for testing technical solutions, identify legal barriers and develop safety standards.

[20] 'Renewable fuels of non-biological origin' such as hydrogen or synthetic fuels

- Ensure that (future) legislation on built environment heating remains tech-neutral to keep options open for hydrogen (e.g., re-use of the distribution network, fuel flexibility targets for heating devices, etc.).

- Incorporate (future) solutions (e.g., domestic hydrogen energy storage) in EPB/EPC schemes, so that they can also be valorised.

7.6 General: Flemish hydrogen strategy and support framework

Where specific, detailed development of hydrogen's continued roll-out in Flanders is concerned, the following recommendations are made:

- Establish a hydrogen policy platform, along the lines of cases like the ETS policy platform and heat networks policy platform.

- Set up a long-term Flemish and Belgian hydrogen policy strategy with a coherent financial support policy for pilot projects and scaling up; that will provide companies with sufficient confidence to launch investments and develop the domestic market.

- Develop an innovation programme (cf. Moonshot programme) for hydrogen R&D projects.

- Develop an investment programme (cf. IPCEI) to construct new infrastructure.

8 Further explanation of recommendations and link to European directives

8.1 Production of hydrogen and hydrogen-based energy derivatives

Exempting electricity used for renewable hydrogen production from taxes and charges

To begin with, **DOUBLE-TAXATION MUST BE AVOIDED**. Taxing the electricity used to produce hydrogen only to then tax the hydrogen itself as a product is unreasonable. Belgium already exempts facilities from system charges on the *storage* of electricity connected to the transmission network, but only in the strict sense, i.e., if what is stored is reconverted into electricity.[21]

At the European level, the 'Energy System Integration Strategy' announced that network costs and taxes will no longer be charged twice for energy storage and hydrogen applications. This will be further implemented by amending the network code directives and the Energy Taxation Directive[22]. Naturally, it will then be up to the Member States to translate these amended directives into national laws and regulations.

Belgium's recommended course is to **EXPAND THAT EXEMPTION** to cover other hydrogen applications. For example, Germany has already introduced an exemption for hydrogen produced through water electrolysis.[23]

GOs and certificates for renewable and low carbon hydrogen

Producers that produce renewable and low-carbon hydrogen can generate GOs, which can be traded on trading platforms. That provides producers with another potential source of revenue.

The European **GUARANTEES OF ORIGIN SYSTEM** for green gas and hydrogen is still under development. The exact criteria for recognising hydrogen as 'renewable' (in terms of the renewable energy in transport target) are still being developed and will be available by the end of 2021. This is a highly specific part of REDII (Article 27) that requires government attention because how it is put into practice could vary from one Member State to another. There is also a need for low-carbon hydrogen GOs.

Flanders has developed a legal framework for renewable hydrogen GOs, with Fluxys as product registrar and VREG as the issuing body. However, procedural details will need to be worked out in greater detail once the first concrete cases get off the ground.

The Hydrogen Industry Cluster recommends that Flanders work towards **HARMONISING ITS GO SCHEME WITH THE OTHER REGIONS AND THE OTHER MEMBER STATES WHEREVER POSSIBLE** to maximise future GO trading opportunities. To this end, Flanders has already distinguished itself as a pioneer. VREG is an

[21] Ref ELIA rates
[22] European Commission (n.d.), Revision of the Energy Tax Directive. Retrieved from https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12227-Revision-of-the-Energy-Tax-Directive-
[23] http://www.gesetze-im-internet.de/enwg_2005/__118.html: hydrogen electrolysis plants commissioned between 2011 and 2026 are exempt from network charges for 20 years.

active partner of the AIB[24], which is currently working on integrating gas GOs within the EECS[25] regulations.

To expand GOs to e-fuels, GO legislation in Flanders will also require amendment.

Taxation of energy carriers based on greenhouse gas intensity

Taxing energy carriers based on their fossil CO_2 emissions will be a key **LEVER** for creating a level playing field for **SUSTAINABLE HYDROGEN** and derived energy carriers vis-a-vis fossil fuel energy carriers.

In Europe, the European Energy Taxation Directive[22] is currently being amended to streamline it with the EU's environmental and climate policy.

There is also currently a revision proposal for the VAT directive before the Council of the European Union and the European Parliament, in which the European Commission is creating greater flexibility in the differentiation of tax rates for different sectors or products.[26]

8.2 Distribution and storage infrastructure

Hydrogen's role in technical pipeline requirements is covered by the Gas Law[27] which stipulates the technical rules and safety requirements for the transport of gaseous and other products through pipelines. That said, no specific requirements (percentage, quality, etc.) are available on blending hydrogen into the natural gas network.

The natural gas market's liberalisation, set in motion by the EU Directive of 2003, obliges the Member States to open up the natural gas network to all producers; however, this only applies to the transport of natural gas. As of yet, there is no legal framework for the free transport of hydrogen.

In addition to large-scale transport of hydrogen, CO_2 transport will also need to be prioritised to further developments in carbon capture and use. Here too, however, **A LEGISLATIVE FRAMEWORK IS ABSENT**.

Open access hydrogen network

If hydrogen is used as an energy carrier, it must eventually be treated like other energy carriers. It, therefore, makes sense to work towards an open-access network allowing consumers and producers to exchange hydrogen. Hydrogen transport could then be a regulated activity with rates subject to approval by the regulator (CREG). Nevertheless, it must be kept in mind that the current hydrogen infrastructure has been financed and constructed privately and is also run by private entities as part of their business operations.

At the EU level, a formal framework is being developed for the evolution of hydrogen and CO_2 infrastructure, as announced in the 'Hydrogen strategy for a climate-neutral Europe'[28] and the 'EU

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[24] AIB: Association of Issuing Bodies
[25]European Energy Certificate System
[26] European Commission (2018). *VAT: More flexibility on VAT rates, less red tape for small businesses.* https://ec.europa.eu/commission/presscorner/detail/en/IP_18_185
[27] Gas law: Law on the transport of gaseous products by pipeline (http://www.ejustice.just.fgov.be/cgi_loi/change_lg.pl?language=nl&la=N&cn=1965041230&table_name=wet)
[28] https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

Strategy for Energy System Integration'[29], involving future amendment of the TEN-E network regulation.[30]

In the meantime, the ideas required to enable the **FUTURE TRANSPORT OF HYDROGEN THROUGH OPEN ACCESS PIPELINES** can already get started on the national level.

8.3 Hydrogen in industry

There are few to no incentives to produce or buy renewable or low-carbon hydrogen. And as it currently stands, the Emissions Trading Scheme (ETS) does not provide companies with sufficient incentive to invest in low-carbon raw material production.

Europe's work on support mechanisms

Several initiatives have been announced at the European level as part of the Green Deal:

- The ETS will be reinforced by lowering the cap on free emissions allowances and expanding the scheme to encompass the maritime transport and aviation sectors, bringing it into line with the enhanced EU's 2030 CO_2 emissions reduction targets.
- The 'Carbon Border Adjustment'[31] mechanism, with an initial proposal projected for the second quarter of 2021, aims to mitigate the risk of carbon leakage by putting a carbon price on certain goods imported from outside the EU.

Both initiatives could lend hydrogen a competitive edge because a higher carbon price minimises the price differential between fossil and alternative raw materials or fuels. However, properly incorporating the international context and taking measures to mitigate the risk of *carbon leakage* remain essential to ensuring that investments required in Flanders and Europe can take place.

In addition to carbon market mechanisms, the EC's hydrogen strategy also contemplates introducing renewable hydrogen quotas in targeted sectors (e.g., in chemicals and transport).

Carbon contracts for difference

There is no question that the mechanisms being developed at European level will steer the production and consumption of low-carbon goods in the long term. Nevertheless, several years will pass before they are successfully implemented and start making a difference.

In the meantime, the first large-scale hydrogen projects need to get off the ground. At this point, however, they will be systematically faced with a substantial operational deficit. Consequently, **(TEMPORARY) SUPPORT SCHEMES** are urgently needed to get these projects up and running, pending further cost reductions in technology and a more robust legal framework.

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[29] https://ec.europa.eu/energy/sites/ener/files/energy_system_integration_strategy_.pdf
[30] https://ec.europa.eu/energy/topics/infrastructure/trans-european-networks-energy_en
[31] European Commission. *EU Green Deal (Carbon Border Adjustment Mechanism).* Retrieved from https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12228-Carbon-Border-Adjustment-Mechanism

Several countries (Germany, France, the UK, etc.) are considering supporting principles such as 'Carbon Contracts for Difference'. Essentially, this means that for a fixed time, national governments will offset the difference between the EU ETS CO_2 price and what the actual CO_2 price should be, to compensate the price differential between low carbon and conventional products (by sector).

Support mechanisms can be implemented either at the European level (e.g., via ETS Innovation Fund) or a national one. Compliance with state aid guidelines[32] will need to remain a point of focus in this respect.

Specific support for pilot projects in Flanders

In the coming years, targeted Flemish investment aid will be needed to roll out the first projects on an industrial scale, and this to help offset the initial low cost efficiency of these facilities.

8.4 Hydrogen in transport

In transport, hydrogen can be used in a variety of sectors and be deployed using diverse technologies. Derived liquid fuels can also be used as 'e-fuels', which could be blended with fossil fuels in a transitional period (cf. today's biofuel blending), or they could be used as an alternative fuel (non-blended).[33]

Several clear CO_2 emissions reduction targets have been set at the European level for transport applications that are intended to provide a strong incentive for battery and fuel cell electric vehicles and low carbon fuels. Key REDII targets include 14% renewable energy in transport by 2030[34] and a 25% reduction of CO_2 emissions for heavy-duty transport by 2025, to be further reduced to 30% by 2030[35]. By 2030, cars and vans should see a reduction of 37.5% and 31% in carbon emissions, respectively.[36]

Lack of infrastructure and limited availability of hydrogen-powered vehicles

Where hydrogen-powered vehicles are concerned, the main obstacle to scaling up is lack of infrastructure (filling stations), which in turn results in fewer users. However, because only a limited number of vehicles are available to visit the first stations, the stations are not profitable. And because Belgium lacks a clear hydrogen policy, hydrogen vehicle OEMs are reluctant to launch their products on the Belgian market.

In terms of public transport, no concrete plans or commitments are in place for the use of hydrogen-powered buses yet. Despite the mention of hydrogen as a potential option for new buses in the current management agreement between the Flemish government and De Lijn (2017-2020; extended to 2021[37]), the focus has remained on urban centres and battery-electric vehicles for zero-emission targets. Specific targets for regional buses, where hydrogen may often be the best alternative, were not included.

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[32] State aid guidelines for energy and environmental protection

[33] In accordance with standard NBN EN 15940 - Paraffinic diesel fuel from synthesis or hydrotreatment

[34] https://ec.europa.eu/jrc/en/jec/renewable-energy-recast-2030-red-ii

[35] Regulation (EU) 2019/1242 of 20 June 2019 setting CO_2 emission performance standards for new heavy-duty vehicles

[36] https://ec.europa.eu/clima/policies/transport/vehicles/regulation_en

[37] https://static.delijn.be/Images/Beheersovereenkomst%202017-2020_tcm3-1100.pdf

Flanders has hit an awkward point in terms of road freight transport because while the first vehicles are entering the market, the region continues to lack the infrastructure required to immediately attract these first commercial vehicles. No framework is available for converting construction and agricultural vehicles. The new European target (21/10/2020) links agriculture funding to sustainability and climate neutrality.

There is no infrastructure whatsoever for inland waterway transport, and the legislative framework for building and operating hydrogen-powered vessels is also markedly absent. This requires further development at the international level within the CCNR (The Central Commission for the Navigation of the Rhine, made up of Germany, France, Switzerland, the Netherlands, Belgium and Luxembourg); the first initiatives to this end have been launched.

Widespread regulatory amendments are required on several fronts (technical and fire regulations, bunker procedures, crew regulations, etc.). The objective is to create a hydrogen technology standard for inland navigation.

Lack of legislation on e-fuels

There is a significant legislative gap, in general, when it comes to the use of RFNBOs[38](e-fuels) as a fuel, and current fuel standards prohibit blending with e-fuels. Moreover, e-fuels have not been included in Belgium's federal climate plan. This stands in contrast with the EU, which offers the Member States, via the REDII[39], the option of including RFNBOs – in addition to biofuels – such as hydrogen or derived e-fuels and recycled carbon fuels in their renewable energy transport targets. The Belgian climate plan takes a purely pragmatic approach by only targeting biofuels (i.e., an achievable objective) and fails to comply with the principle of technology neutrality. In turn, this stifles market incentive to develop RFNBOs.

The need for a hydrogen mobility rollout plan

A ROLLOUT PLAN FOR A REFUELLING INFRASTRUCTURE NETWORK, drawn up in consultation with the sector (filling station operators, transport federations such as Febetra, Febiac, ACEA, etc., vehicle manufacturers, etc.) and that provides sufficient coverage for Flanders, at minimum, is needed.

At the European level, the directive on the rollout of alternative fuel infrastructure is scheduled for review in 2021[40]; this is likely to set concrete targets for hydrogen filling stations.

Exemption from taxes and charges for zero-emission heavy-duty transport vehicles, e.g., no or low **TOLLS FOR ZERO-EMISSION HGVS** could spur the development and use of hydrogen-powered HGVs in Flanders.

For public transport, The Hydrogen Industry Cluster recommends that the new management agreement between the Flemish Government and De Lijn include a **PLAN FOR THE FUTURE GREENING OF INTERCITY BUSES**, in which sufficiently large hydrogen pilot project(s) could be started. Buses are an excellent means of developing the hydrogen infrastructure because they operate along fixed routes and can quickly ensure filling station profitability due to their guaranteed dependence.

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[38] Renewable Fuel of Non-biological Origin
[39] REDII, Article 25
[40] European Parliament (2020). Towards a revision of the Alternative Fuels Infrastructure Directive. Retrieved from

To stimulate hydrogen use in inland waterway transport, **PILOT PROJECTS** require funding. That way essential testing of technical solutions for vessels and refuelling infrastructure can take place and the experience needed in vessel safety protocol can be gained. Flanders must also continue to play an active role in the CCNR to develop the general legal framework on inland navigation-related alternative fuels (especially H_2 and methanol) and fuel cells/fuel engines.

Amending fuel legislation to develop the RFNBOs market

The REDII Directive stipulates that **BELGIUM MUST INCORPORATE RFNBOS IN THE BELGIAN FUEL LAW** and develop a method to monitor contributions to the 14% target. Belgium must also actively follow up the development of delegated acts within the framework of the REDII at the EU level. Creating a level playing field with other alternatives such as biofuels and battery-electric vehicles (e.g., multipliers) is a top priority.

8.5 Hydrogen in the built environment

For hydrogen use in the built environment, clear insight into optimal hydrogen-based technical solutions, in addition to the other energy-efficient and/or CO_2-neutral solutions (heat pumps, heat networks) is still lacking. Conversely, full electrification of the built environments power and heat supply is obviously not tenable in a carbon-neutral society.

Furthermore, a legal framework (safety standards) has not been developed for hydrogen use in the built environment, despite safety being an inherently important factor. The built environment, like other sectors, suffers from prohibitively high costs of technology and hydrogen compared to those that of today's fossil fuels.

Testing solutions on a pilot scale and developing appropriate legislation

Flanders needs to provide **PILOT PROJECTS** with support essential for testing technical solutions – often developed by Flemish SMEs –, identifying legal obstacles, and developing safety standards.

(Future) legislation on building heating needs to be **TECH-NEUTRAL** and hydrogen options need to be kept open (e.g., re-use of the distribution network, fuel flexibility targets for heating devices, etc.)
(Future) solutions, e.g., domestic hydrogen energy storage, must be incorporated in EPB/EPC schemes so that they can also be valorised.

8.6 General: Flemish hydrogen strategy and support framework

Stakeholders and the government are co-evaluating how to strengthen certain developments in Flanders as part of a specific policy platform. For example, the German hydrogen policy strategy proposes a similar policy platform for the implementation of its hydrogen policy strategy. To this end, streamlining with the other regions and the federal level, or at least ensuring smooth coordination with them, is of pivotal importance.

A long-term Flemish and Belgian hydrogen policy strategy with a coherent support policy for pilot projects and scaling up is essential for bolstering company confidence to launch investments and develop the domestic market.

9 Conclusions

The Hydrogen Industry Cluster developed this Flemish hydrogen strategy (2025 - 2030) proposal to establish a policy for an integrated government hydrogen strategy at both the Flemish and federal level.

- Hydrogen technology is high on the (inter)national political agenda, and the hydrogen industry is also notably well represented in Flanders. The time is now.

The Hydrogen Industry Cluster is appealing to Flanders, as a region, to become involved in the international hydrogen debate and affairs. Not only will that contribute to a **CARBON-NEUTRAL ENERGY SYSTEM**, but it will also make **SUSTAINABLE ECONOMIC GROWTH** in Belgium a reality. In addition to an excellent industrial network across the hydrogen value chain, Flanders also enjoys environmental conditions conducive to the development of a hydrogen economy.

To simplify matters, The Hydrogen Industry Cluster has identified a range of **HYDROGEN PRIORITIES** for Flanders. The first is to transition from the current huge quantities of grey hydrogen to sustainable alternatives, as a green raw material for Flemish industry. The second point is *heavy-duty* transport, for which there are hardly any alternatives. The built environment must also be prioritised given its potential to meet heat and electricity demand. Its potential exceeds electricity generation in the power sector.

The goal is to significantly increase domestic sustainable hydrogen production capacities over the next decade, keeping the limited renewable energy capacity of Flanders in mind. To compensate for these limitations, The Hydrogen Industry Cluster recommends importing renewable hydrogen from regions with better solar and wind capacity. Sustainable hydrogen can be supplied to end users along a 'Flemish H_2 backbone'. However, not only should supply be increased, but demand for sustainable hydrogen needs to be stimulated across a multitude of sectors as well.

The industry's goal in publishing this paper is to announce its willingness to invest in related technology. Where the public authorities are concerned, the demand is for a guaranteed **LEVEL PLAYING FIELD** for current fossil-fuel technologies and competing low or zero-emission techniques. An integrated government policy strategy also ensures a logical succession of future projects that will make the journey through the infamous *valley of death* somewhat more bearable.

The Hydrogen Industry Cluster makes specific recommendations to the Flemish and federal authorities. Hydrogen technology's presence in some fields is new and, as a result, requires a degree of legislative amendment. At the same time, The Hydrogen Industry Cluster appeals to the authorities to become an *early adopter* of any EU legislative initiatives and to prioritise hydrogen in respect thereof.

In **short**, everything needed to make a substantial contribution to a carbon-neutral Flanders is within reach. Moreover, hydrogen will make it possible for that Flanders to enjoy sustainable economic growth. This piece seeks to contribute to making that a reality. It is also a clarion call to all stakeholders with a will to lend a hand towards achieving a greener future. The Hydrogen Industry Cluster is eager to constructively partner towards a hydrogen economy.

10 Disclaimer

This paper has been drawn up with due care; nevertheless, this does not guarantee the truth, accuracy, or completeness of the information contained herein. As the author of this paper, The Hydrogen Industry Cluster vzw waives all liability for the contents herein.

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